Ministry of the Environment

Ontario

Hon. Keith C. Norton, Q. C., *Minister*
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Water Resources Report 9b

Ontario

WATER RESOURCES REPORT 9b

Evaluation of the Ground Water Responses Applied to the Bowmanville, Soper and Wilmot Creeks IHD Representative Drainage Basin

By
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MINISTRY OF THE ENVIRONMENT
Water Resources Branch

Toronto Ontario

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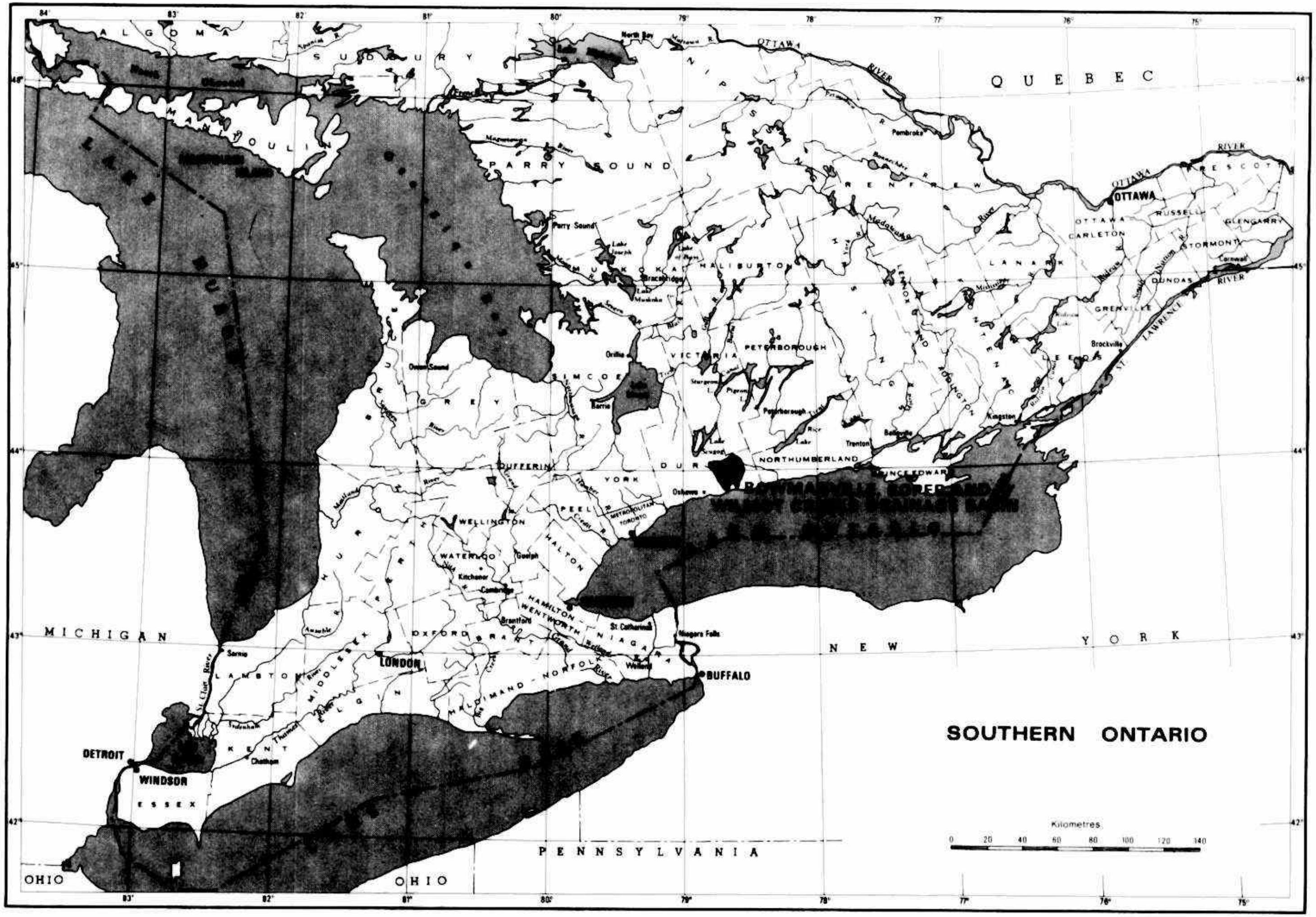

Figure 1. Location of the Bowmanville, Soper and Wilmot creeks drainage basin in southern Ontario.

PREFACE

Part of the contribution of the Ontario Ministry of the Environment to the International Hydrological Decade Program (1965-1974) was the study of the ground water regime in five basins in southern Ontario, each basin being representative of one or more major physiographic and climatic regions in the Province.

This report describes the ground water responses of the Bowmanville, Soper and Wilmot creeks drainage basin. The basin includes three major physiographic units: the Lake Iroquois Plain, the Till Plain (the South Slope), and the Oak Ridges interlobate moraine.

INTRODUCTION

Purpose and Scope of the Investigation

The Canadian National Committee for the International Hydrological Decade (IHD), in its publication entitled "Guidelines for Research Basin Studies, 1966", defined representative basins as areas designated for the study of hydrologic systems in selected physiographic and climatic regions.

Part of the contribution of the Ontario Ministry of the Environment to the IHD program is the study of the hydrology and hydrogeology of five basins in southern Ontario, each being representative of major physiographic and climatic regions in the Province.

Major objectives of this study in the Bowmanville, Soper and Wilmot creeks drainage basin are to better understand the inter-relationships between ground water and other components of the hydrologic cycle, to arrive at reasonable estimates of the hydrogeologic parameters, to determine the amounts of ground water recharge, discharge and change in storage and their variations in time and space and finally, to incorporate the results into a ground water model.

A broader purpose of the investigation in this basin is to examine the limits of representativeness of the study area and to identify the larger physiographic and climatic environments which include this "representative" basin.

Detailed field investigations were made of the surficial geology. Aerial photographs obtained from the Ministry of Natural Resources were used to supplement geologic studies. In addition, data on the meteorology, streamflow, soil moisture, and ground water levels were collected through the co-operation of Environment Canada and local residents. These data are summarized in hydrologic and ground water budgets.

Hydrologic processes (i.e. precipitation, snowmelt, soil moisture, evapotranspiration, surface runoff and ground water) are discussed in relation to climatic conditions and physiographic and geologic characteristics of the study area.

The estimated hydrogeologic parameters (i.e. transmissivities and storage coefficients) and the computed ground water recharge amounts were used as input to a digital computer program to simulate the observed changes in ground water level elevations in response to variable recharge.

Location

The Bowmanville, Soper and Wilmot creeks basin is in southern Ontario on the north side of Lake Ontario between longitudes 78° 35' and 78° 51' W, and latitudes 43° 53' and 44° 04' N (Figure 1) in the Regional Municipality of Durham.

The basin has an area of about 270 km^2, a length of about 18 km in a northwest-southeast direction and a width which varies between 6 and 14 km in an east-west direction.

The basin is bounded on the south by Lake Ontario, on the east by Graham Creek and the Ganaraska River, on the north by the Scugog and the Pigeon lakes drainage system, which constitute a part of the Trent River system, and on the west by several small river systems, the chief of which are the Black, Forewell and East Oshawa creeks. All of these systems drain into Lake Ontario.

Previous Investigations

The stratigraphy of the bedrock underlying the study area has been described by Caley (1940), Chapman and Putnam (1951), Liberty (1955 and 1969), Beards (1967) and Hewitt (1972).

Information on the Pleistocene deposits in the study area was published by Wilson (1905, 1908), Coleman (1909, 1932 and 1936), Keele (1924), Chapman and Putnam (1951), Gravenor (1957), Barouch (1971), Singer (1973, 1974), and Funk (1977).

A report by Puccini (1967) gives an analysis of the 1966-1967 snow survey data obtained from the Wilmot Creek basin. An estimate of the basin-wide water equivalent from snowpack depth measurements, using four years of snow observation data in the Wilmot Creek basin, was given by Logan (1972). Two papers by Logan (1975) describe a computer aided snowmelt model for augmenting winter streamflow simulation and the sensitivity of a hydrologic system model to sampling errors in recorded data. In both papers, Logan used data from the Wilmot Creek basin.

Quick and Fleischer (1970), examined the effects of natural stream channel changes on streamflow measurements using data from several streamflow gauging stations within the study area.

Two reports by Barouch (1971) deal with hydrograph separation in the Wilmot Creek basin using recession factor analysis and chemistry of streamflow and with an evaluation of the ground water storage capacity in the Soper Creek sub-basin using a physical parametric appraoch.

Singer (1974) describes the hydrogeology along the north shore of Lake Ontario in the Bowmanville-Newcastle area. A paper by Singer (1975) describes the simulation of the ground water dynamic response to natural stresses in the Wilmot Creek basin using a digital computer program based on the finite difference technique.

A general evaluation of the ground water resources and hydrochemistry of the Bowmanville, Soper and Wilmot creeks drainage basin is given by Funk (1977).

A report on soils in the County of Durham accompanied by a soil map was prepared by Webber et al (1946).

Acknowledgements

This work was carried out under the general supervision of Mr. D. N. Jeffs, Director, and Mr. F. C. Fleischer, Supervisor of the Water Modelling Section, all of the Water Resources Branch, Ontario Ministry of the Environment. Mr. R. C. Hore, Supervisor of the Hydrology and Monitoring Section was responsible for the development of the study and subsequent data collection activities under the original IHD program. Numerous discussions with Dr. J. Coward formerly of the River Systems Unit, were most helpful and are gratefully acknowledged.

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The co-operation of the residents of the area, who kindly assisted in the collection of meteorologic and hydrologic data and permitted the use of abandoned wells on their properties as observation wells, is greatly appreciated.

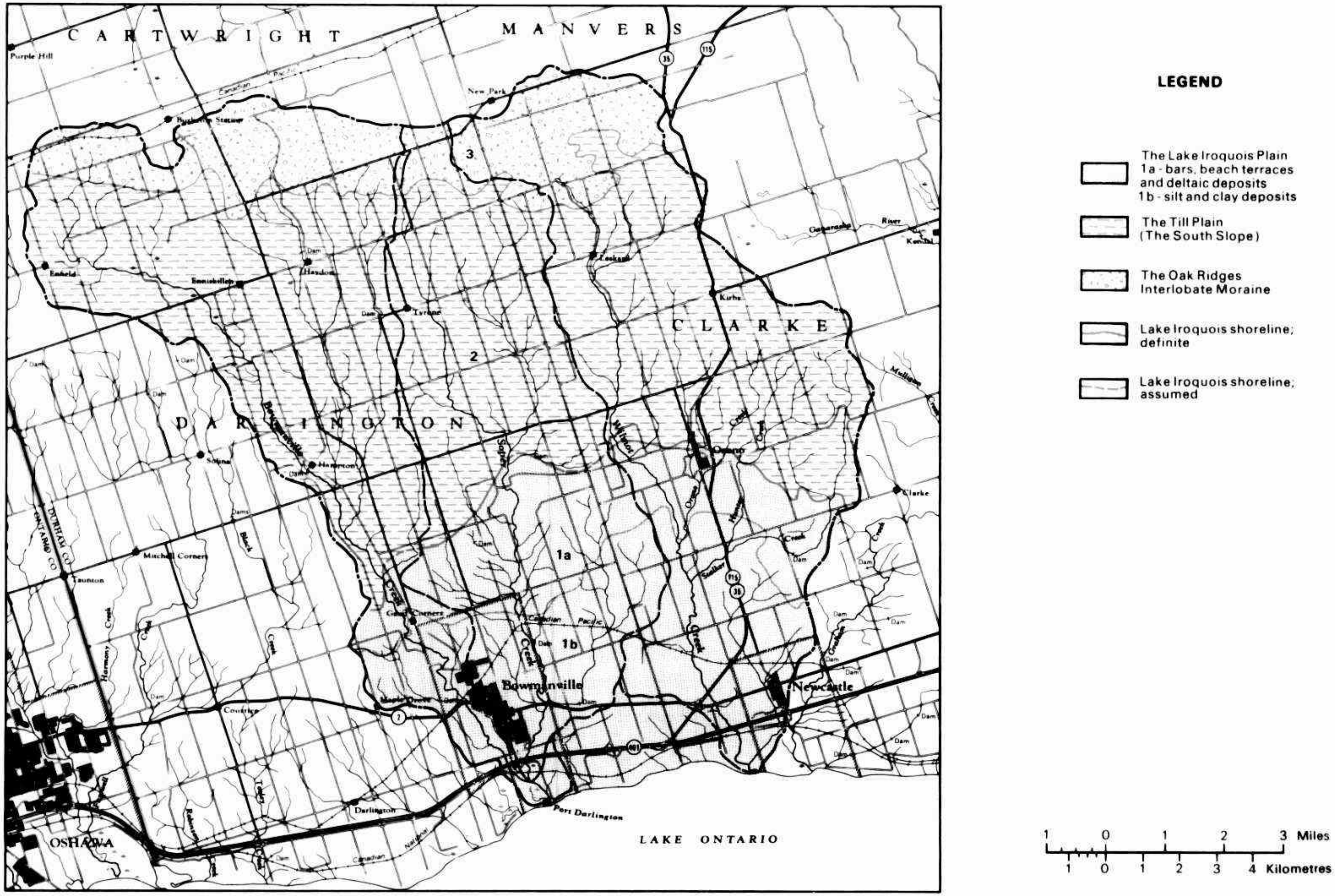


Figure 2: Physiographic divisions and drainage in the study area.

GEOGRAPHY

PHYSIOGRAPHY

Topography

The topography of the Bowmanville, Soper and Wilmot creeks basin is a direct result of the deposition and erosion processes during glacial and post-glacial times. Land surface elevations vary from 74 m at Lake Ontario to about 375 m above mean sea level (m.s.l.) in the extreme northeastern part of the drainage basin.

The three major physiographic units in the study area, the Lake Iroquois Plain, the Till Plain (the South Slope), and the Oak Ridges interlobate moraine (Figure 2), were originally described by Chapman and Putnam (1951) and later by Gravenor (1957).

The Lake Iroquois Plain... After the retreat of the last glacier, the present lake Ontario basin was occupied by a glacial lake, Lake Iroquois. the lake reached higher levels than Lake Ontario. The abandoned Lake Iroquois shoreline lies from 6 to 10 km north of the present-day shoreline of Lake Ontario and tilts upwards to the east in the area. The elevation of the Iroquois shoreline is about 157 m at the western end of the drainage basin, increasing gradually to reach approximately 161 m at its eastern end. In some places, where the beach was protected by sand and gravel bars, the exact position of the abandoned shoreline is not clear and has to be approximated from a knowledge of the present topography and post-glacial tilt.

Sand and gravel bars and beach terraces are well displayed at surface along the abandoned shoreline. Large deltas were formed at the mouths of the Bowmanville, Soper and Wilmot creeks as they emptied their waters into Lake Iroquois or a lower level post-glacial lake, creating a belt up to 3 km in width to the south of the abandoned shoreline. For the most part, this belt is composed of fine gravel and sand. Farther south, the offshore deposits of Lake Iroquois consist mainly of silts and varved clay.

In the eastern, central and northwestern parts of the Iroquois Plain, till is exposed locally at surface. In addition, two small drumlins located to the northeast of the Town of Bowmanville interrupt the plain.

The Lake Iroquois Plain slopes down towards Lake Ontario with an average slope of about 10 m per km. In the upper part of the Iroquois Plain, within the deltaic belt, the relief is nearly flat with an average slope of about 9 m per km. Below the deltaic belt, the rolling surface of the Iroquois Plain is interrupted by till rises that reach over 137 m above m.s.l. in the eastern part of the study area and about 122 m in the western part of the study area. The land surface along the shore of Lake Ontario rises abruptly as bluffs above the lake. The bluffs diminish to less than 1 m near the mouths of major streams entering the lake and reach a maximum height of over 15 m in the central area, midway between the mouths of Bowmanville and Wilmot creeks.

The Till Plain (The South Slope...) The Till Plain is the second major physiographic unit within the drainage basin, extending over most of its central parts. The total relief of this unit is about 135 m, measured from the abandoned Lake Iroquois shoreline to the base of the Oak Ridges interlobate moraine, with an average slope of approximately 17 m per km.

Chapman and Putman (1951) considered this plain as a part of the South Slope physiographic unit which extends from the Niagara Escarpment to the Trent River and covers about 2433 km^2. In doing so, Chapman and Putnam related this plain to the Lake Ontario ice lobe. Gravenor (1957) mapped this till plain as a part of the Peterborough Drumlin Field physiograhic unit which creates the impression that the plain is associated with the Lake Simcoe ice lobe. Gravenor, however, did so out of convenience, as he was unable to delineate the boundary between the Lake Ontario and Lake Simcoe ice lobes. Indeed, there is no field evidence of a moraine marking the southernmost advance of the Lake Simcoe ice lobe which suggests that the ice of both lobes was confluent and upon

stagnation, left no marginal moraines. It is most likely, however, that the Till Plain within the study area is associated with the Lake Ontario ice lobe and forms a part of the South Slope physiographic unit.

The topography of the Till Plain varies from regularly gentle to fairly steep slopes, yet presents a noticeable contrast to the irregular features of the Oak Ridges interlobate moraine to the north and the flatter rolling surface of the Iroquois Plain to the south. Streams flowing directly down the slope through the Till Plain have cut deep valleys in the till. In addition, numerous gullies have been cut by intermittent drainage in an east-west direction.

Low, small and scattered drumlines are closely associated with the Till Plain. The dimensions of these drumlines vary from 15 to 30 m in height, 0.15 to 0.5 km in width, and 0.3 to 0.8 km in length.

The Oak Ridges Interlobate Moraine... The Oak Ridges interlobate moraine forms the northern part of the study area and can be classified as kame moraine (Gravenor, 1957). The Oak Ridges moraine stands as one of the most significant physiographic units in southern Ontario, extending from the Niagara Escarpment to the Trent River. It forms the height of land dividing the streams of the study area which flow south into Lake Ontario from those flowing north into Lake Scugog.

The topography of the Oak Rides is characterized by hilly, irregular surfaces, and it is marked by knolls, hummocks and closed depressions. In general, the Oak Ridges forms an elevated plateau which rises sharply above the level of the Till Plain along its southern boundary. Its elevation ranges between 275 and 375 m above m.s.l. with the highest points at the extreme northeastern parts of the study area.

One remarkable feature of the knob-and-basin relief of this physiographic unit is the lack of surface drainage. Therefore, precipitation falling on this area either returns back to the atmosphere through evapotranspiration or infiltrates vertically through the surficial deposits of mainly sand and gravel to recharge the ground water. At the base of both the northern and southern shoulders of the ridges, the ground water issues again as springs or seepage faces to form two belts of discharge zones. The good infiltration characteristic of the Oak Ridges moraine makes it one of the most important ground water recharge regions in southern Ontario.

Within the study area, the ground water discharges at the base of the southern shoulder of the ridges, at an elevation of approximately 275-330 m where the three major streams in the area, the Bowmanville, Soper and Wilmot creeks, start their journey towards Lake Ontario.

Drainage

There are three main drainage systems in the study area, namely the Bowmanville, Soper and Wilmot creeks, all of which flow south-easterly towards Lake Ontario. In addition, there are four small unnamed creeks, with drainage areas ranging from about 1 to 4 km^2, which empty directly into Lake Ontario.

The configuration of these streams and their respective drainages are shown in Figure 2, and the major streams are described below.

Bowmanville Creek... Bownmanville Creek, with its main tributary, Soper Creek, excluded, has a drainage area of 86.47 km^2 and constitutes the largest sub-basin in the area under study.

The main course of this creek rises on the Oak Ridges at an elevation of approximately 305 m and flows in a southeast direction to its outlet into Lake Ontario at Port Darlington.

Bowmanville creek has 14 first order tributaries and numerous second and third order tributaries. One of the major tributaries to Bowmanville Creek is Soper Creek, its confluence being at a marshy bay about 0.8 km upstream from Lake Ontario.

Bowmanville Creek drains a funnel shaped area whose width decreases gradually from approximately 10 km in the Oak Ridges to less than 1 km near Lake Ontario. The length of the main course is 26.6 km. The length of the main course and the first and second order tributaries is approximately 72 km, whereas the total length of the main course and all the tributaries is about 90 km.

Bowmanville Creek has a total fall of approximately 228 m for an average gradient of about 9 m per km.

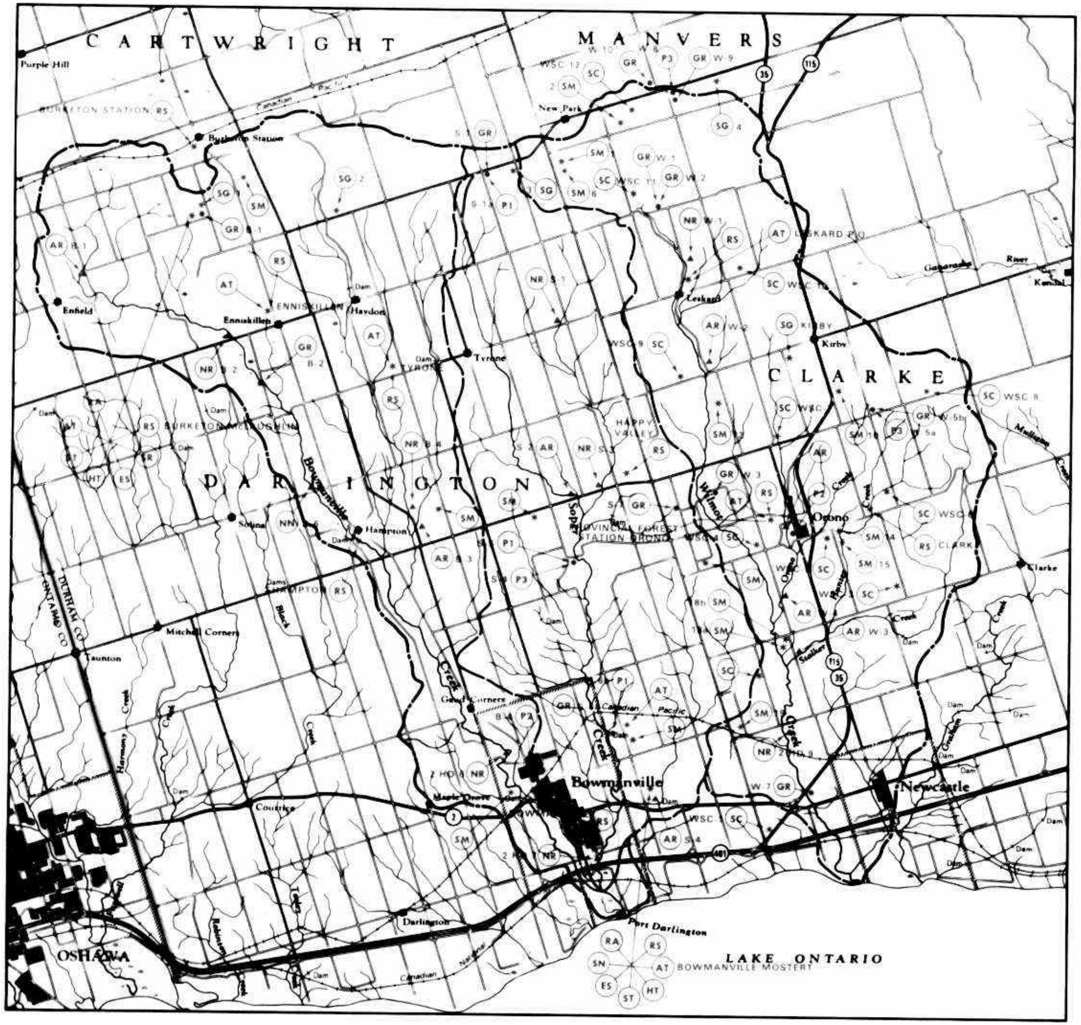
Soper Creek... The Soper Creek drainage basin has an area of about 78 km^2. Its headwaters rise on the Oak Ridges at elevations ranging from 280 to 290 m. The creek flows southerly to its confluence with Bowmanville Creek about 0.8 km north of Port Darlington at an elevation of approximately 75 m.

The Soper Creek, being itself a first order tributary to Bowmanville Creek, has 20 second order tributaries and numerous third and fourth order tributaries.

The main course of Soper Creek has a length of 20.2 km and a total fall of 204 m, for an average gradient of approximately 10 m per km. The overall length of the main course and all the tributaries is 96 km.

Wilmot Creek... Wilmot Creek drains the eastern portion of the area under study and, with a total area of 88.8 km^2, is the second largest sub-basin in the drainage system.

Wilmot Creek rises on the Oak Ridges at an elevation of 331 m, approximately 3 km north of the village of Leskard and flows south-easterly to its outlet on Lake Ontario.



LEGEND

NR	Hydrometric station, natural control, recording
NN	Hydrometric station, natural control, non-recording
AR	Hydrometric station, artificial control, recording
GR	Groundwater well, recording
P*	Piezometer (asterisk replaced by number of piezometers in nest)
SC	Snow course
SG	Snow gauge
RA	Rain gauge, recording
RS	Rain gauge, standard
HT	Hygrothermograph
SN	Radiometer
SR	Sunshine recorder
ES	Evaporation station
SM	Soil moisture site
ST	Soil temperature site
AT	Air temperature site

▲	Streamflow station
•	Groundwater well
*	Meteorological station

1 0 1 2 3 Miles
1 0 1 2 3 4 Kilometres

Figure 3. Basin instrumentation.

Wilmot Creek has nine first order tributaries and numerous second and third order tributaries. The length of the main course of Wilmot Creek is 21.2 km. The length of the main course and the first and second order tributaries is approximately 58 km whereas the total length of the main course and all the tributaries is approximately 98 km. The average gradient of the main course is about 12 m per km.

CLIMATE

The climate of the Bowmanville, Soper and Wilmot creeks drainage basin is characterized by warm summers, mild winters, and a long growing season with usually reliable rainfall. It is mildly influenced by the proximity of Lake Ontario.

The local variations in climate reflect variations in topography, the proximity to Lake Ontario and also the prevailing winds. The annual variations are dependent on the nature and frequency of the weather systems which cross the area.

Putnam and Chapman (1938) described the study are as lying within two climatic regions: "the Lake Ontario Shore", and "the South Slope". The "Lake Ontario Shore" climatic region as outlined by Putman and Chapman, corresponds roughly to the Lake Iroquois Plain physiographic unit where a definite moderating influence due to Lake Ontario is observed. The remainder of the area, between the abandoned Lake Iroquois shoreline and the northern boundaries of the drainage basin, falls within the "South Slope" climatic region. The climate of this area does not enjoy the direct modifying influence of Lake Ontario, nevertheless it does not differ appreciably from that of the "Lake Ontario Shore" climatic region.

Temperature

Temperature data are collected at four main meteorological stations within the study are (Figure 3). These stations are: Leskard, McLaughlin, Mostert and Orono. The Orono meteorological station is the only long term station in the area where records on temperature have been assembled since May, 1923. The other three stations are short term and were established for the IHD program.

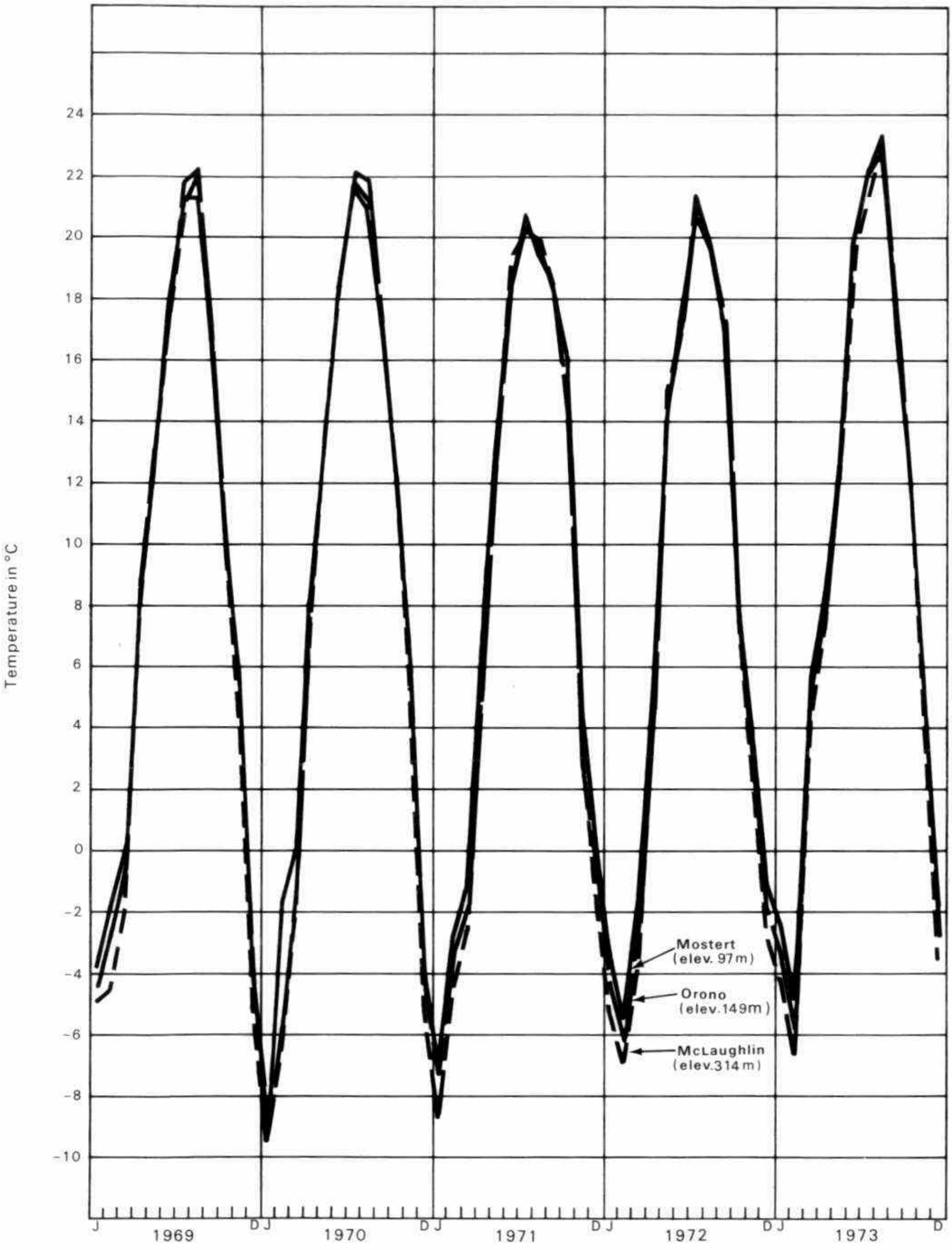


Figure 4. Monthly temperature variations in the study area as measured at Mostert, Orono and McLaughlin meteorological stations.

Concurrent daily maximum and minimum temperatures are available for the four stations since January, 1969. Table 1 gives the monthly, annual and 5-year mean temperatures as measured at these four stations for the period 1969-1973. The table indicates that the mean monthly temperatures throughout the study area are basically the same during the spring and fall seasons.

The lowest mean monthly temperatures are observed during the winter season in the months of January or February. In this season, also, the mean monthly temperatures observed at Mostert station, which is located near Lake Ontario, is 1 to 2^{O}C higher than that registered at McLaughlin station, which is located in the north-western part of the study area. The readings at Orono station, which is located in the center of the Wilmot Creek basin, are intermediate between those of Mostert and McLaughlin stations.

The highest mean monthly temperatures are recorded during the summer season in the months of July and August. Mostert station during this season registers the lowest values most of the time. this is due to the cooling effect of the Lake Ontario breeze. Correspondingly, Orono station registers the highest values and McLaughlin station the intermediate values. The lower values observed at McLaughlin station, in comparison with Orono station, (Figure 4) reflect to a certain extent, the higher elevation at McLaughlin.

The temperature data from the Orono station are given in Table 2 as an approximation of the long term temperature variations within the study area. The noral annual temperature at this station for the period (1941-1970) is 6.95^{O}C, with a maximum temperature of 39.44^{O}C recorded on July 10, 1936 and a lowest temperature of -34.44^{O}C recorded on Feburary 8, 1934.

Precipitation

Precipitation data are collected at nine meteorological stations within the study area. The names of these stations and their locations are given in Table 3 and Figure 3, respectively. Two of these stations, namely Mostert and Bowmanville STP, are located within the "Lake Ontario Shore" climatic region, whereas the rest are distributed throughout the "South Slope" climatic region.

Over 50 years of daily precipitation data are available for Orono station, whereas the remaining stations were established more recently for the IHD program. Concurrent historical records are available for the nine stations since January, 1968.

Detailed discussions of the variation of precipitation in relation to the hydrologic cycle are given under the Hydrology Section of this Report. In most general terms, it is possible to conclude that precipitation over the study area increases from the south along the Lake Ontario shoreline towards the north in the Oak Ridges.

The precipitation data from the Orono station are given in Table 4 as an approximation of the precipitation within the study area. The 30-year (1941-1970) normal annual precipitation at this station is 868 mm and is made up of 704 mm of rain and 1638 mm of snow.

Table 3 Precipitation Stations in the Study Area

Station	Type of Measurement	Date of Record
Bowmanville STP	Manual	September, 1967
Clark	"	June, 1966
Hampton	"	June, 1966
Happy Valley	"	January, 1966
Leskard	"	June, 1966
McLaughlin	Recording	May, 1967
Mostert	"	November, 1967
Orono	Manual	May, 1923
Tyrone	"	June, 1967

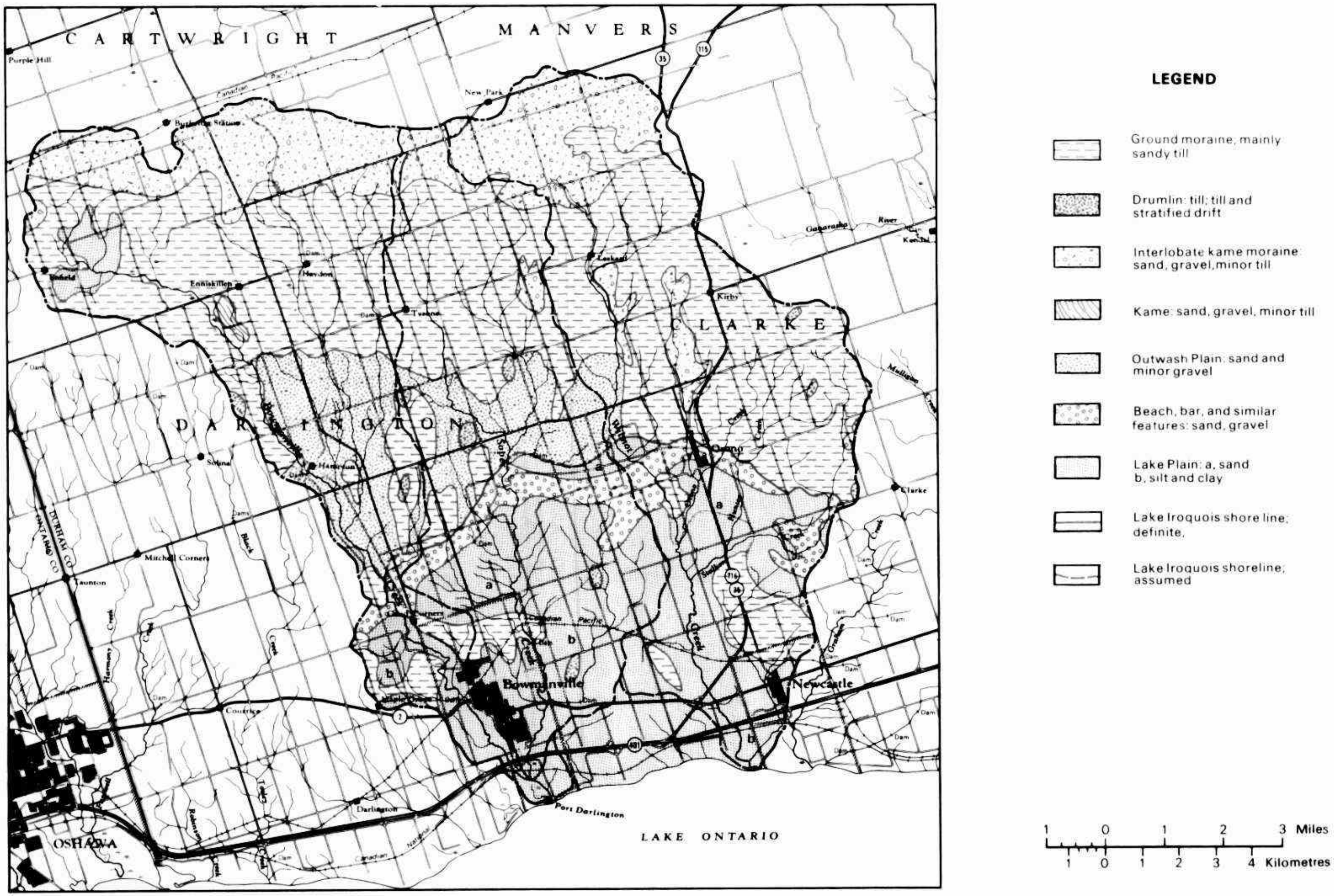


Figure 5. Surficial geology of the study area as given by Gravenor, 1957.

GEOLOGY

BEDROCK GEOLOGY

The bedrock in the Bownmanville, Soper and Wilmot creeks basin is obscured by overlying deposits of glacial drift. Data from water well records, on file with the MOE, indicate that the elevation of the bedrock along the Lake Ontario shoreline ranges from 59 m to 71 m increasing gradually northward to reach 152 m in the Oak Ridges (Singer, 1974; Funk, 1977).

St. Mary's Cement Quarry which is approximately 800 m north of Lake Ontario, to the southwest of the Town of Bowmanville, reveals an excellent section of the bedrock. The overburden in the quarry extends to a depth of about 9 m. It is underlain by dark, brownish black shales (0-6 m thick), which in turn overlie dark, bituminous limestone. The areal extent of the shales appears to be limited to the western part of the study area, as their presence is not reported in water well records east of the Wilmot Creek.

According to Liberty (1969), the shales belong to the middle and lower members of the Whitby Formation from the Nottawasaga Group which is Upper Ordovician in Age. The limestones belong to the Lindsay Formation from the Simcoe Group which is Middle Ordovician in Age. The bedrock stratigraphy is given in Table 5.

SURFICIAL GEOLOGY

General Description and Distribution

The overburden within the study area consists of glacial, glacio-fluvial and glacio-lacustrine deposits of Pleistocene Age with minor amounts of alluvial, swamp and bog deposits of Recent Age (Figure 5).

In general, the overburden thickens northward from less than 6 m along the Lake Ontario shoreline to about 215 m along the Oak Ridges interlobate moraine (Singer, 1974).

The type and areal distribution of the deposits which outcrop at the land surface are given on a geologic map published by Gravenor in 1957. These deposits may be classified into the following four types according to their origin:

1 - Glacial deposits which include the ground moraine and closely associated drumlins;
2 - Glacio-fluvial deposits which include the Oak Ridges interlobate moraine, an outwash plain and a kame;
3 - Glacio-lacustrine deposits which include the proglacial lake deposits and the Lake Iroquois beach and bars deposits;
4 - Minor amounts of alluvial, swamp and bog deposits of Recent Age which overlie, locally, the above-mentioned deposits.

Glacial Deposits

Ground Moraine and Drumlins...Ground moraine which is composed mainly of sandy till forms a till plain that covers most of the Bowmanville, Soper and Wilmot creeks basin. Most of the ground moraine lies between the abandoned Iroquois shoreline on the south and the base of the Oak ridges interlobate moraine to the north. Within these limits, the ground moraine constitutes a part of the South Slope physiographic unit described by Chapman and Putnam (1951). A second and smaller area of the ground moraine extends to the south of the Lake Iroquois shoreline and constitutes a part of the Lake Iroquois Plain physiographic unit.

A few well formed, oval shaped drumlins, composed of sandy till with abundant stones, are scattered within the study area.

The ground moraine and the drumlins are closely associated and both are believed to be related to the Ontario ice lobe.

Glacio-Fluvial Deposits

The Oak Ridges Interlobate Moraine... The Oak Ridges interlobate moraine was built between two opposing ice lobes, namely, the Lake Ontario ice lobe advancing from the east and the Northern lobe, a predecessor of the later Simcoe lobe, advancing from the north (Gravenor, 1957).

Data collected from deep observation wells drilled in the Oak Ridges indicate that the moraine has a capping of sand and gravel with minor amounts of silt and till up to 100 m in thickness. The sand and gravel capping is underlain by sequences of glacial and glacio-fluvial material up to 149 m in thickness. Gravenor (1957) reported a surprising lack of incorporated till in the interlobate moraine as only one stream cut, in over one hundred examined, showed a mixture of till and gravel. Gravenor (1957) concludes that the melting of the ice between the two ice lobes was rapid and the floods of water pouring out left much stratified material, but little till.

No evidence of till laid down by the Lake Simcoe ice lobe was observed in the Oak Ridges within the study area. Patches of till that were left on top of the moraine by the Simcoe lobe in parts of the Oak Ridges outside the study area were reported by Dean (1950), Chapman and Putnam (1951) and Gravenor (1957).

Outwash Plains... An area of outwash sediments is found south of the Oak Ridges interlobate moraine and immediately north of the abandoned Lake Iroquois shoreline, extending between Bowmanville Creek to the west and Wilmot Creek to the east.

The outwash sediments are composed mainly of sand with minor amounts of gravel. These sediments were probably deposited in temporary lakes which were formed by the melted ice of the Lake Ontario lobe as it retreated backward into the Ontario basin, ponding meltwaters in front of itself to the north.

Kame... A small area to the southwest of the village of Enniskillen was identified by Gravenor (1957) as kame. The kame area is composed of sand, gravel and minor amounts of till and it was built, probably, in contact with the ice.

Glacio-Lacustrine Deposits

As was indicated previously, there is one major lake plain in the study area, that of Lake Iroquois. The Lake Iroquois sediments were deposited along and to the south of the abandoned Lake Iroquois shoreline.

Sand and gravel bars and beach terraces are common all along the Lake Iroquois shoreline. The thickness of these deposits ranges from 1 to 8 m. Further, on the lakeward side, a sandy belt up to 3 km in width was formed parallel to the Lake Iroquois shoreline.

Logs of water wells drilled within this sand belt and located to the southwest of Gaud Corners on Bowmanville Creek, approximately 1.5 km to the south of Stephens Gulch on Soper Creek and immediately to the south of Orono on Wilmot Creek, indicate the presence of sand beds that have a continuous thickness of over 30 m. The origin of these sands is unclear. They may be deltaic deposits formed at the mouths of Bowmanville, Soper and Wilmot creeks as they entered Lake Iroquois, or a lower level postglacial lake. On the other hand, the upper most few meters of these deposits could be associated with Lake Iroquois, while their lower part could be correlated with older deposits.

Farther south, the offshore deposits of Lake Iroquois consist mainly of silts and varved clays up to 8 m in thickness.

In the eastern, central and northwestern parts of the Iroquois plain, till is exposed at surface. The exposed till has a surface elevation equal to or lower than the silts and varved clays of Lake Iroquois which indicates that it was flooded by water. Gravenor (1957) believes that these low lying till surfaced areas represent those locations where strong currents prevented the deposition of silts and clays.

RECENT GEOLOGY

Stream Terrace Deposits

Along most of the main stream valleys there are several terraces formed when the streams were flowing at higher levels. The terrace deposits are composed of mixtures of gravel, sand, silt and clay.

Lake Ontario Deposits

Along most of the Lake Ontario shoreline within the study area, there is a beach of gravel and sand between the base of the bluffs and the lake. These sediments are the product of the erosion of the bluffs and their thickness varies from a few centimeters to approximately one meter.

In several localities, sand bars have been built across bays. The most important bays enclosed by these barriers are the harbour of Port Darlington on Bowmanville Creek and the harbour of Newcastle on Wilmot Creek.

Swamp and Bog Deposits

Swamp and bog deposits are found in the lagoons that are enclosed by the beach bars. They consist of marl, gyttja and organic matter with a thickness up to 1 m.

STRATIGRAPHY

In order to determine the origin, type and areal distribution of deposits within the overburden and to arrive at a better understanding of the subsurface geology, a number of wells were drilled at various locations within the study area (Figure 3). Core samples were collected from these wells for grain size and carbonate analyses. The results of these analyses, together with geophysical loggings of the wells (gamma ray and resistivity loggings) were used to arrive at a more precise picture of the vertical and areal distribution of various types of deposits.

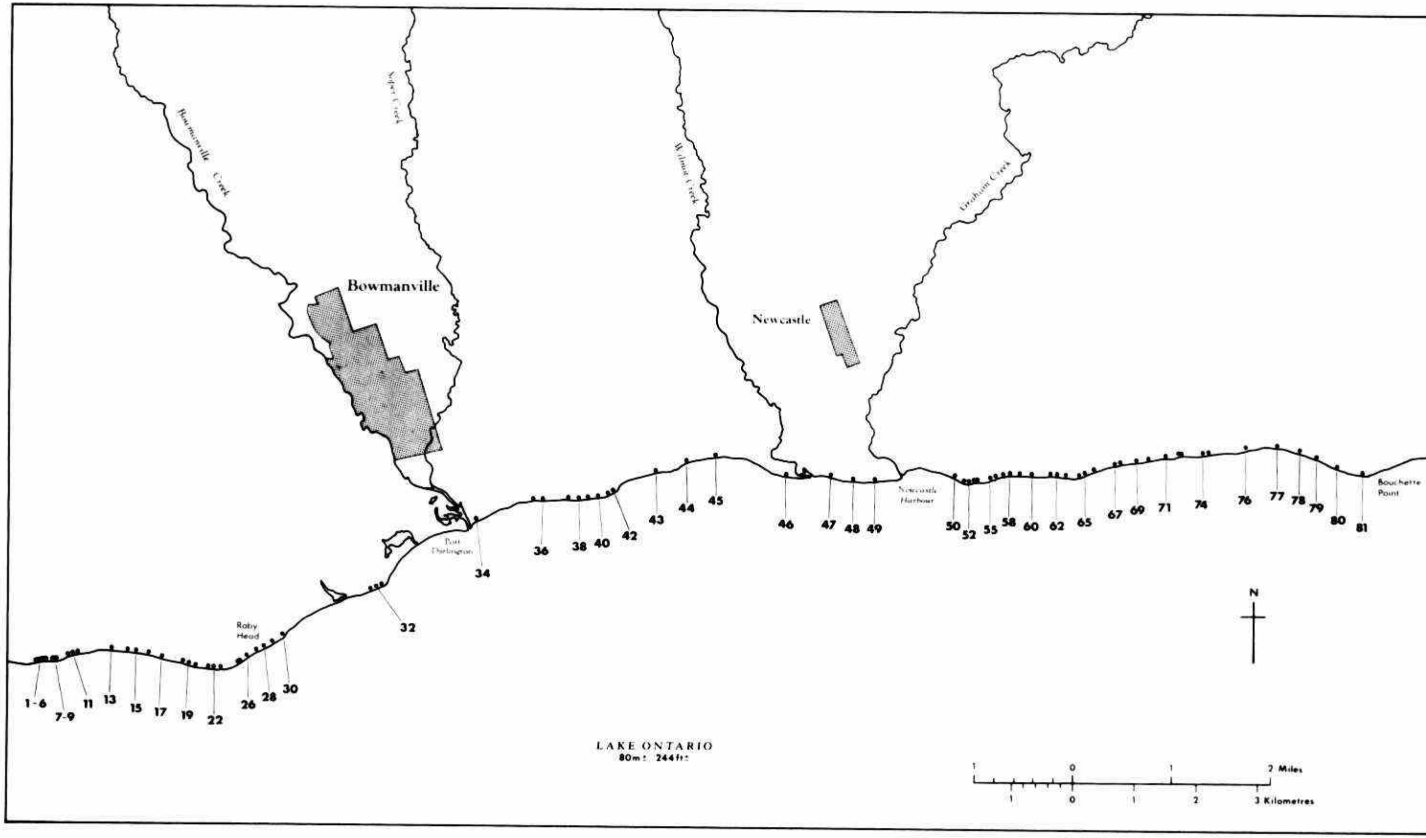


Figure 6. **Locations of measured sections along the north shore of Lake Ontario in the Bowmanville-Newcastle area.**

In addition, a detailed examination of the overburden geology of the bluffs along 24 km of the Lake Ontario shore from longitude 78^{O} 29' W to longitude 78^{O} 46' W was underaken (Figure 6. Singer, 1974) and an attempt was made to correlate the various stratigraphic units as exposed in the bluffs with similar units encountered in the drilled wells.

The stratigraphic succession as exposed in the bluffs along the examined shoreline indicates that five major units are present (Singer, 1974). These units are:

1 - a Proglacial Lake Unit consisting mainly of varved clay;
2 - an Upper Glacial Unit made up of two till sheets separated by glacio-fluvial sands and silts;
3 - a Middle Glacial Unit composed of till;
4 - The Clarke Deposits Unit, consisting of a lower part of glacio-lacustrine clays and an upper part of glacio-fluvial sands;
5 - a Lower Glacial Unit composed of till.

The correlation of these deposits with those in the Toronto area is discussed in Singer, (1974).

The stratigraphic succession as revealed in wells drilled in the Oak Ridges area (Figure 7) indicates the presence of at least five major units. These units are:

1 - an Upper Glacial Unit, consisting of a lower part of glacial till and an upper part of glacio-fluvial sands and gravel with occasional patches of till;
2 - the Clarke Deposits Unit, consisting of a lower part of glacio-lacustrine clays and an upper part of glacio-fluvial sands;
3 - a Lower Glacial Unit composed of till;
4 - a Lower Glacio-fluvial Unit composed of sand;
5 - a Basal Glacial Unit composed of till.

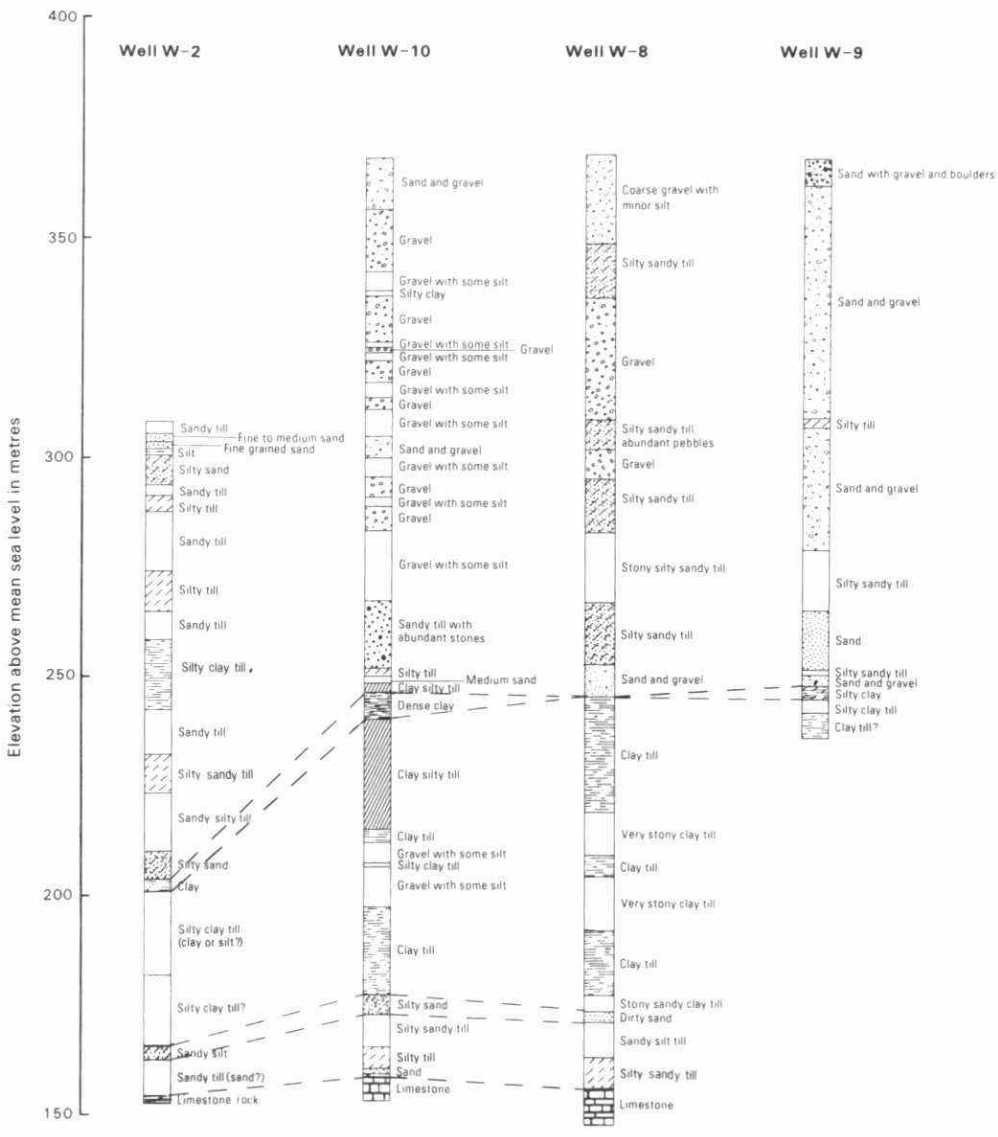


Figure 7. Geologic logs of deep wells drilled in the Oak Ridges area of the Bowmanville, Soper and Wilmot creeks basin.

The Basal Glacial Unit

The Basal Glacial Unit is made up of till and has been identified in three wells (W-2, W-8 and W-10) located in the Oak Ridges area (Figure 7). No evidence of the presence of this till is available in the bluffs along the southern edge of the study area. The till rests on top of the bedrock and its thickness ranges from 13 to 15 m.

Samples collected from this till indicate that it is a sandy to sandy silt till with abundant shale fragments. Mechanical analyses on four samples of this till average 5.3% clay, 9.2% silt and 85.5% sand. Carbonate analyses (4 samples) aerage 23.1% calcite and 7.1% dolomite, with a calcite to dolomite ratio of 3.2. Details of the till analyses of samples collected from wells drilled in the study area are given in Table 6.

The Lower Glacio-Fluvial Unit

Available data from wells W-2, W-8 and W-10 located in the Oak Ridges (Figure 7), indicate the presence of a glacio-fluvial unit overlying the basal Till. The unit is composed of silty sand and ranges in thickness from 3 to 5 metres.

The Lower Glacial Unit

The Lower Glacial Unit consists of till and is exposed in the bluffs at some locations in the western, central and eastern parts of the examined shoreline, as described by Singer (1974). In the intervening areas this till does not outcrop, but may be present below lake level. A similar till was identified in wells W-2, W-8, W-9 and W-10 which are located in the Oak Ridges area (Figure 7) and also in well B-4 located in the City of Bowmanville (Figure 8). Data from records on file with the MOE of water wells located near the shoreline of Lake Ontario, indicate that this till rests on top of the bedrock here. However, this till overlies the Lower Glacio-Fluvial Unit in the Oak Ridges area. The thickness of the till along the bluffs of Lake Ontario ranges from less than 1 m to a maximum of 10 m above lake level. On the other hand, the thickness of the till in the Oak Ridges area ranges from 31 to 71 m.

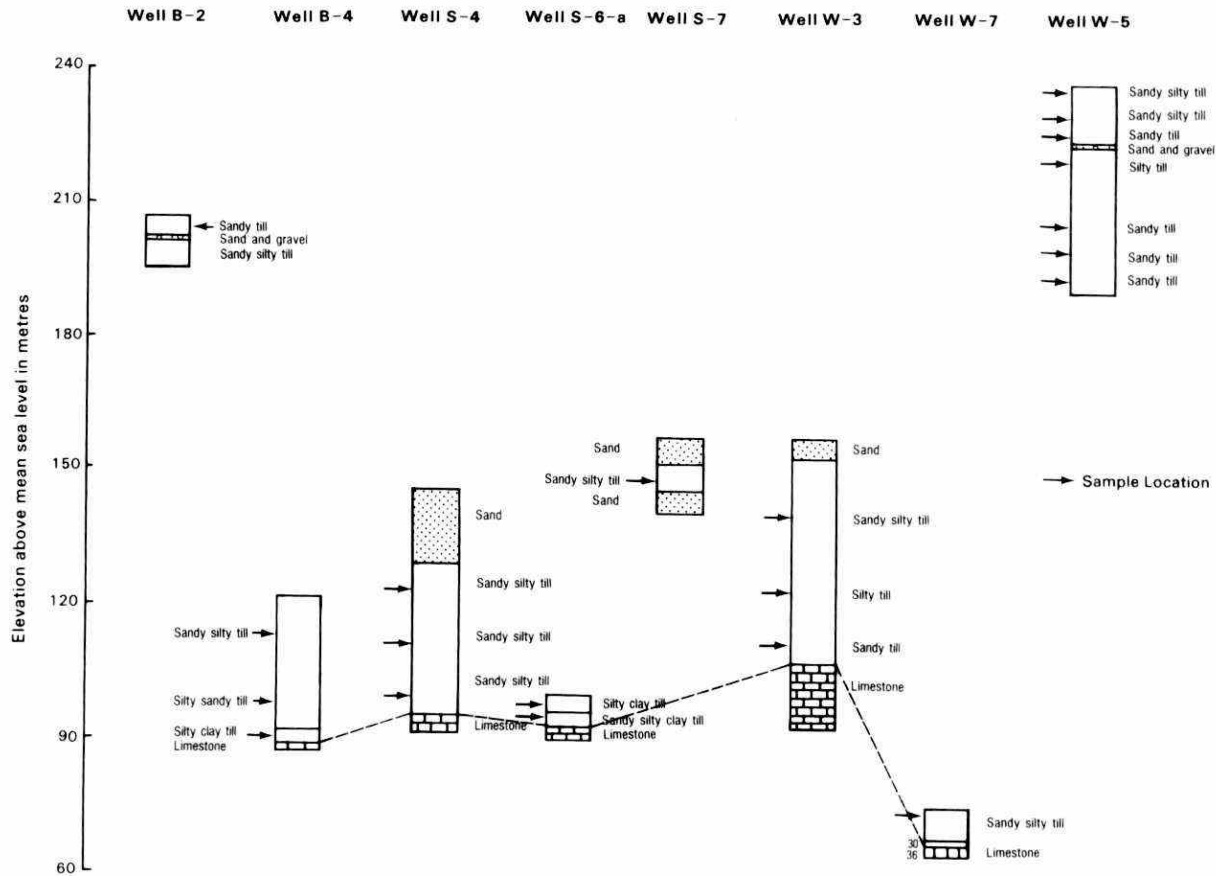


Figure 8. Geologic logs of wells drilled in the central and southern portion of the Bowmanville, Soper and Wilmot creeks basin.

Samples collected from the bluffs indicate that the Lower Till is a compact, dense silt to clay silt till with a very low pebble content. Analyses of nine samples yield average values of 31.6% clay, 51.6% silt and 16.8% sand. The till matrix averages 21.0% calcite and 7.1% dolomite with a calcite to dolomite ratio of 2.9.

Nine core samples of this Lower Till obtained from wells drilled in the study area north of the lakeshore show that the till, in general, is also silty to clayey silt in composition. Analyses of these samples indicate an average of 28.7% clay, 40.1% silt and 31.3% sand. Carbonate analyses averaged 27.9% calcite and 8.9% dolomite, with a calcite to dolomite ratio of 3.1. Details of the till analyses for the shoreline area are given in Table 7.

Available data do not allow the delineation of the exact areal distribution of this unit throughout the study area; however, they indicate that the unit is missing in places, which is probably due to the erosion processes that occurred after the unit was laid down. The lower till is comparable with the Sunnybrook Till described by Karrow (1967) in the Scarborough area, which was assigned an early Wisconsinan Age.

The Clarke Deposits Unit

Within the examined shoreline, a variety of stratified clay, silt and sand deposits that have a complex areal distribution, overlies the Lower Till. Coleman (1909) names these the deposits of the "Clarke Interglacial Period". These deposits can be divided into two parts: a lower part consisting of varved clay or thin bedded clayey silt and an upper part made up of sand.

The varved clay deposits were identified mainly in the western part of the examined shoreline. The thickness of the varved clay deposits reaches a maximum of 7 m. Analyses of three samples yield average values of 35.0% clay, 58.0% silt and 7.0% sand. Carbonate analyses from these samples average 32.0% calcite and 8.2% dolomite, with a calcite to dolomite ratio of 3.9.

Logs of wells W-2, W-9 and W-10 located in the Oak Ridges area (Figure 7) reveal the presence of a similar clay layer up to 8 m in thickness, overlying the Lower Till.

The lower part of the Clarke Deposits in the eastern end of the examined bluffs consists mainly of well sorted, evenly bedded, grey coloured clay silt beds having a maximum thickness of 4 m. Analyses of five samples average 35.5% clay, 46.0% silt and 18.5% sand. The matrix material contains 49.6% calcite and 5.5% dolomite, with a calcite to dolomite ratio of 9.7.

The upper part of the Clarke Deposits Unit in the bluffs concists of well sorted, yellow brownish, very fine to fine sand. The maximum thickness of this sand in the western part of the shoreline reaches 9 m, while it attains a thickness of over 22 m in the eastern part.

Logs of wells W-2, W-8, W-9 and W-10 located in the Oak Ridges area indicate the presence of a similar sand layer ranging in thickness from 1.5 to 1.7m and overlying the clay layer or the Lower Till (Figure 7).

The lithological composition of the Clarke sediments along the bluffs of Lake Ontario, as well as in the Oak Ridges area, suggests that the lower part of the varved clay and clayey silt is lacustrine and was deposited in a system of proglacial lakes. The upper sand part is indicative of shallow water or deltaic conditions in high level lakes. The notion regarding the probable existence of a system of lakes during this period of time within the study area is based on the fact that the elevation of the Clarke sands along the bluffs is approximately 100 m, whereas their elevation in the Oak Ridges area is approximately 250 m. Therefore, it is conceivable to suggest the presence of at least two lake systems at that period within the study area: a low level lake system over the lower parts of the study area and a high level lake system in the Oak Ridges area.

The general similarity between the Clarke Deposits and the Thorncliffe Formation described by Karrow (1967) in the Scarborough area, suggests a possible correlation. The Clarke Deposits can be regarded as mid-Wisconsinan interstadial deposits.

The Middle Glacial Unit

The Middle Glacial Unit is made up of till. Exposures of this till have only been identified in the western end of the examined shoreline. At present, no evidence is available to indicate the presence of this unit in the Oak Ridges within the study area.

The thickness of the till ranges from 1.5 to 3.6 m. On a fresh surface, the clayey silt till is dark brown, compact and has a low pebble content. In texture, it resembles the Lower Till. Analyses of four samples yield an average of 32.4% clay, 53.9% silt and 13.7% sand. Analyses of the till matrix (4 samples) average 34.0% calcite and 6.5% dolomite, with a calcite to dolomite ratio of 5.5.

The stratigraphic position of this till on top of the Clarke Deposits and its lithologic character suggest that this deposit is a result of an ice advance correlative with that of the mid-Wisconsinan Meadowcliffe Till in the Scarborough area.

The Upper Glacial Unit

The Upper Glacial Unit is the youngest glacial deposit exposed in the bluffs and forms the surface material in most of the study area. In the Oak Ridges area, however, the unit has a capping of sand and gravel, with minor amounts of silt and occasional patches of till, ranging in thickness from 10 to 100 m.

Outcrops of this unit in the bluffs indicate that it is made up of two lithologically similar tills, separated by sand and silt deposits up to 14 m in thickness. In places the stratified deposits are missing and the two tills merge into one undifferentiated complex.

The lower till of this unit is grey in colour and varies in thickness from less than 1 m to over 12 m. Analyses on 14 samples of this till average 12.6% clay, 38.4% silt and 49.0% sand. Carbonate analyses on 15 samples of this till average 36.5% calcite and 7.0% dolomite, with a calcite to dolomite ratio of 5.2.

The upper till of this unit, as exposed in the bluffs, is oxidized and buff in colour and its thickness ranges from 2 to 13 m. Analyses on 18 samples of this till yield an average of 12.3% clay, 37.0% silt and 50.7% sand. Carbonate analyses (18 samples) on the till matrix average 39.3% calcite and 6.1% dolomite, with a calcite to dolomite ratio of 6.5.

A similar glacial unit made up of one or two till sheets was identified in most of the wells drilled in the study area. Analyses on 36 samples of till collected from these wells average 9.3% clay, 29.8% silt and 60.9% sand. Carbonate analyses on 33 samples average 38.3% calcite and 6.8% dolomite, with a calcite to dolomite ratio of 5.6.

The results of the mechanical and carbonate analyses and the discontinuity of the stratified deposits separating the two tills of this unit indicate that both till sheets are closely related. They represent two ice advances from the same ice lobe. The Upper Glacial Unit in the study area is correlative with the Halton till (previously known as the Leaside Till) described by Karrow (1967, 1974).

The stratified sediments, as exposed in the bluffs, separating the two tills of this upper unit consist mainly of silt and very fine, compact sand. Similar sediments are present in a number of wells drilled in the study area, while they are missing in others (Figures 7 and 8). The presence of stratified sediments is indicative of a warm period accompanied by an ice retreat. It is most likely that the sand and gravel capping which outcrops at surface in most of the Oak Ridges within the study area, was formed during this warm

period. This sand and gravel capping is resting on the top of a sandy silty till which is probably the lower till sheet of the Upper Glacial Unit. The upper till sheet of this unit covers only the southern flank of the Oak Ridges moraine which indicates that the last advance of the Lake Ontario ice lobe failed to override the ridges.

The Proglacial Lake Unit

An area of outwash sediments is found south of the Oak Ridges interlobate moraine and immediately north of the abandoned Lake Iroquois shoreline, extending between Bowmanville Creek to the west and Wilmot Creek to the east. On the other hand, several clay, silt, sand and gravel deposits are displayed at surface within the Lake Iroquois physiographic unit.

The outwash sediments were probably deposited in temporary lakes which were formed by the melting ice of the Lake Ontario ice lobe, as it retreated into the Ontario basin, ponding meltwater in front of itself to the north. The sediments within the Lake Iroquois Plain were deposited either in early peripheral lakes or in Lake Iroquois, preceding Lake Ontario.

Recent Deposits

Along most of the main stream valleys several terraces were formed when the streams were flowing at higher levels. At the same time, shore erosion has produced a beach of gravel and sand between the base of the bluffs and the lake. In addition, swamp and bog deposits are found in several lagoons in the study area. All these deposits are of Recent Age.

Table 6. Analysis of Till Samples Collected from Wells Drilled in the Bowmanville, Soper, and Wilmot Creeks Basin.

Well No	Approx Depth Interval (m)	Mechanical Analysis			Carbonate Analysis			Material
		Sand %	Silt %	Clay %	Calcite %	Dolomite %	Cal/Dol	
B-2	0-4	92.0	6.0	2.0	33.6	5.8	5.8	Upper Till
B-4	8-13	47.0	39.0	14.0	43.2	7.7	5.6	Upper Till
	23-29	34.0	42.0	24.0	39.2	6.5	6.0	Upper Till
	30-32	11.0	61.0	28.0	36.0	7.8	4.6	Lower Till
S-1	0-11	32.0	60.0	8.0	30.2	2.8	10.8	Upper Till
S-4	24-29	44.0	33.0	23.0	37.8	6.0	6.3	Upper Till
	32-40	40.0	36.0	24.0	38.0	5.7	6.7	Upper Till
	40-46	77.0	13.0	10.0	48.8	7.7	6.3	Upper Till
S-6-a	2-4	10.0	35.0	55.0	59.0	5.7	9.7	?
	4-9	56.0	26.0	18.0	46.0	7.0	6.6	?
S-7	11-12	50.5	43.7	5.8	31.2	6.8	4.6	Upper Till
W-2	27-32	87.0	11.0	3.0	25.4	7.8	3.3	Upper Till
	35-36	87.0	11.0	2.0	29.6	7.8	3.8	Upper Till
	36-37	88.0	11.0	1.0	32.2	7.2	4.5	Upper Till
	39-42	66.0	30.0	4.0	42.8	6.4	6.7	Upper Till
	47-49	53.0	38.0	9.0	41.6	6.8	6.1	Upper Till
	58-65	53.0	30.0	17.0	48.0	5.2	9.4	Upper Till
	68-71	54.0	42.0	4.0	22.0	10.0	2.2	Upper Till?
	71-77	72.0	24.0	4.0	25.0	8.8	2.8	Upper Till?
	77-85	66.0	28.0	6.0	-	-	-	Upper Till?
	107-116	19.0	39.0	44.0	24.9	8.9	2.8	Lower Till
	105-153	77.0	21.0	2.0	8.6	4.7	1.8	Basal Till
W-3	25-38	49.0	38.0	13.0	41.6	5.8	7.2	Upper Till
	38	22.0	64.0	14.0	29.8	7.8	3.8	Upper Till
	46-51	73.0	15.0	12.0	59.8	6.8	8.8	Upper Till
W-5-a	0-4	59.5	40.5	0.0	33.6	3.2	9.5	Upper Till
	4-9	50.0	36.0	14.0	44.0	5.8	7.6	Upper Till
	9-12	70.2	26.1	3.7	46.0	5.0	9.2	Upper Till
	19-22	25.9	74.1	0.0	23.4	5.0	4.7	Upper Till
	29-33	72.0	20.0	8.0	40.2	7.2	5.6	Upper Till
	33-39	75.6	24.4	0.0	30.5	5.2	5.9	Upper Till
	39-44	77.0	14.0	9.0	44.9	5.5	8.2	Upper Till
W-7	0-2	42.0	45.0	13.0	4.1	2.3	1.8	?
W-8	21	68.0	18.0	14.0	43.3	5.6	7.7	Upper Till
	62	63.0	26.0	11.0	33.8	6.8	5.3	Upper Till
	78	78.0	13.0	9.0	-	-	-	Upper Till
	88	72.0	17.0	11.0	47.6	5.2	9.2	Upper Till
	111	64.0	21.0	15.0	38.3	6.0	6.4	Upper Till
	117	84.0	7.0	9.0	59.0	8.6	6.9	Upper Till?
	166	68.0	16.0	16.0	20.6	8.4	2.5	Lower Till?
	171	49.0	28.0	23.0	23.8	10.6	2.2	Lower Till
	186	40.0	18.0	42.0	27.1	7.4	3.7	Lower Till
	197	85.0	6.0	9.0	29.0	7.1	4.1	Basal Till
	207	91.0	4.0	5.0	27.5	9.2	3.0	Basal Till
	210	89.0	6.0	5.0	27.5	7.4	3.7	Basal Till
W-9	123	40.0	44.0	16.0	31.2	8.8	3.5	Lower Till
	124	31.0	40.0	29.0	32.4	8.8	3.7	Lower Till
	125	8.0	60.0	32.0	30.8	10.8	2.8	Lower Till
	130	16.0	50.0	34.0	24.8	9.3	2.7	Lower Till
W-10	104	76.0	15.1	8.9	-	-	-	Upper Till

HYDROGEOLOGY

The Hydrologic Cycle

The hydrologic cycle is a concept which considers the processes of motion, loss and recharge of the earth's waters (Gray, 1970).

Water that evaporates from the land and oceans is carried by the air masses and eventually precipitates either on land or oceans. Some of the precipitation that falls on land may be intercepted or transpired by plants and returned back into the atmosphere, some may runoff over the land surface to streams and the remainder may infiltrate into the ground. The infiltrated water may be temporarily retained as soil moisture or move laterally as interflow within the soil to the nearest stream. The remainder percolates deeper to the water table to be stored as ground water. The ground water, in turn, may be used by plants, or flow out as springs, or seep into streams as baseflow, only to be eventually evaporated into the atmosphere to complete the hydrologic cycle.

From the foregoing it is clear that the hydrologic cycle is made up of several components (processes) which are interrelated and in order to study one of these components in detail, it is necessary to examine its relationships with all the other components.

One of the main objectives of this report is to better understand the interrelationships between ground water and other components of the hydrologic cycle in the Bowmvanville, Soper and Wilmot creeks basin. The following example is intended to clarify some of these interrelationships qualitatively as well as quantitatively.

Figure 9 shows the daily precipitation (rain and snow, Leskard station, 1969-1970), the computed daily snowmelt values, the simulated daily snowpack depth in terms of mm of water equivalents, the average daily temperature and the ground water level variations as measured at observation well W-5-B. The water year 1969-1970 can be divided into the following eight periods:

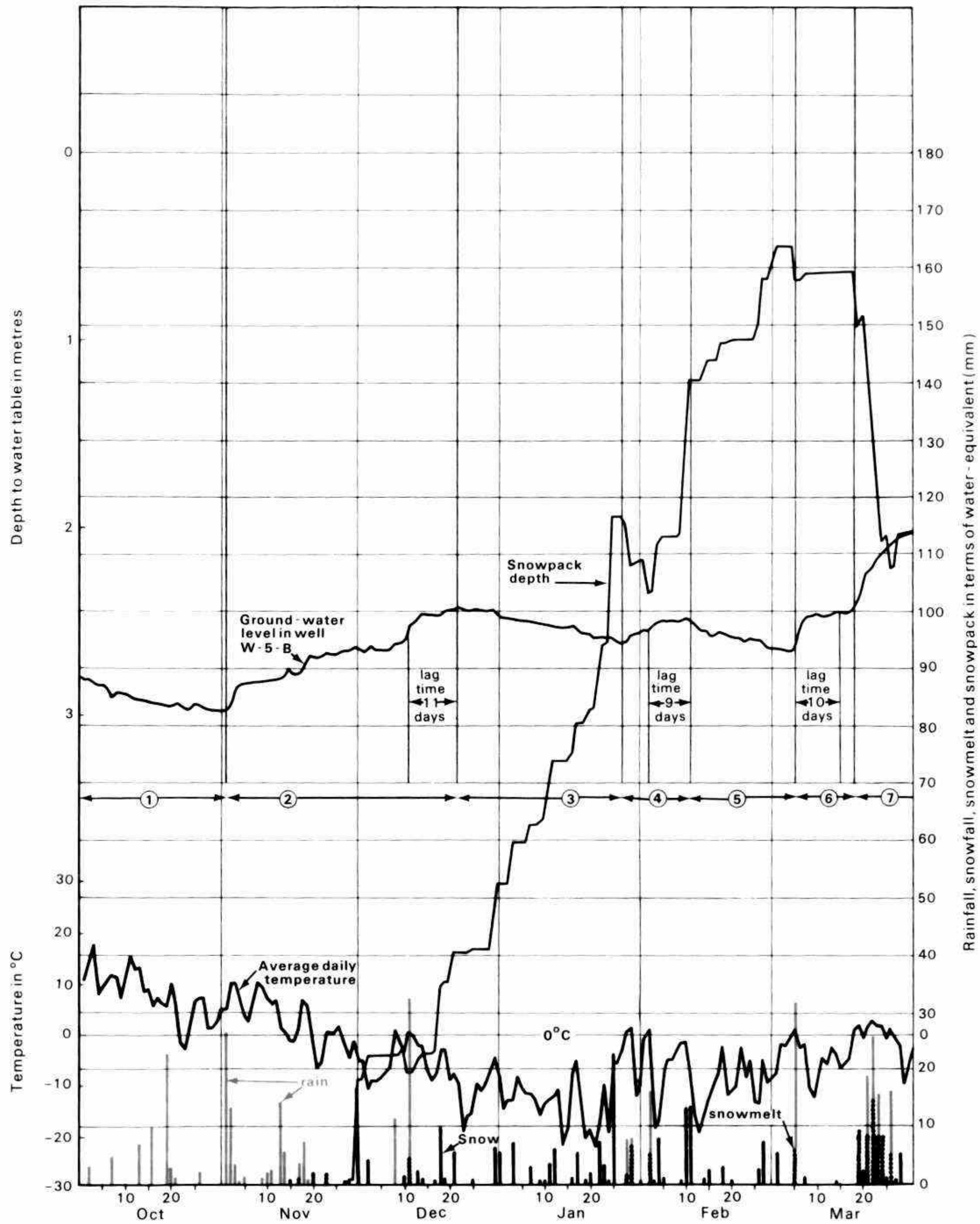
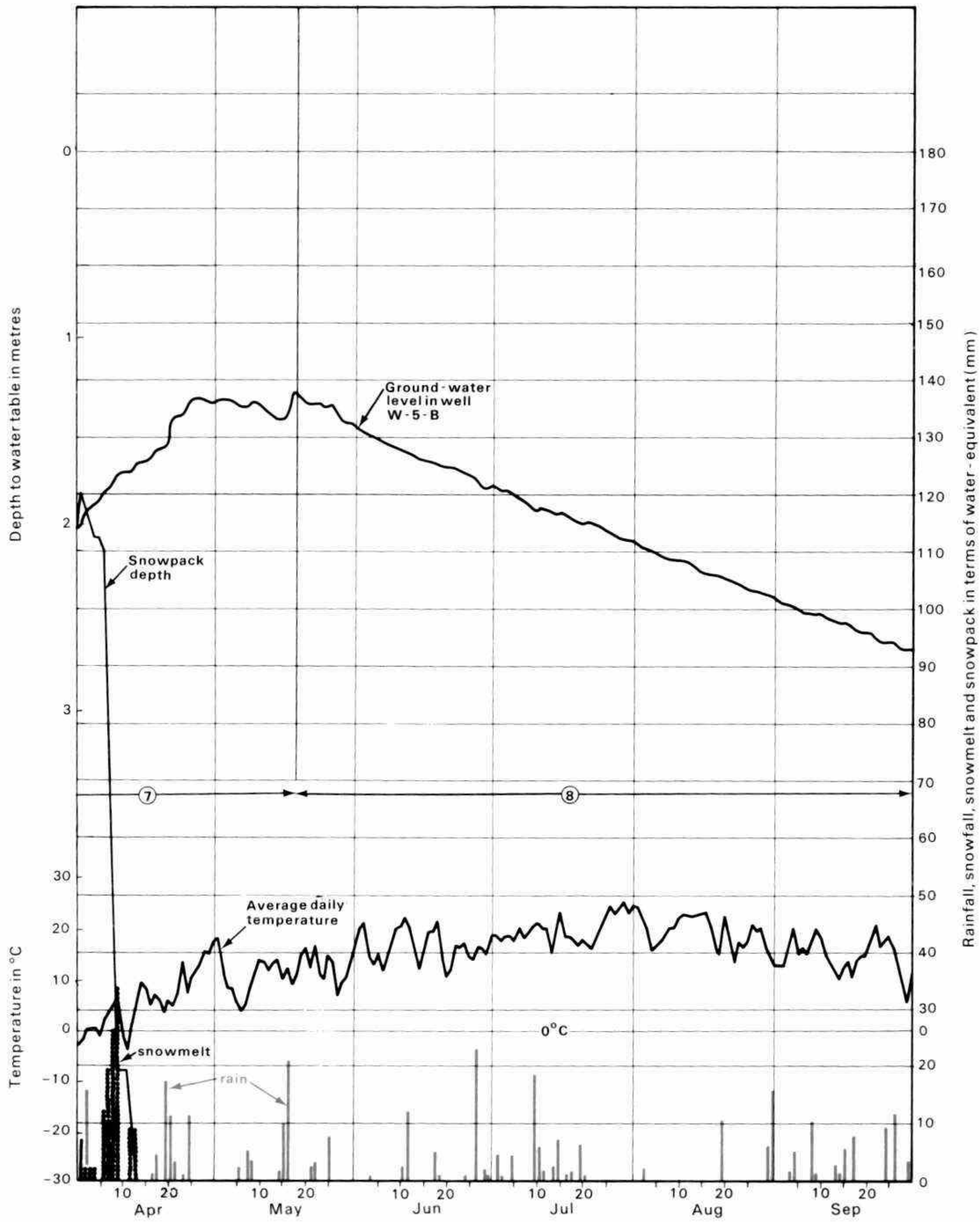


Figure 9. Comparison between precipitation (rain, snow, snowpack depth and snowmelt) and temperature as measured and computed at Leskard meteorological station and ground water levels as measured in well W - 5 - B for water year 1969 - 1970.



Depth to water table in metres
Rainfall, snowfall, snowmelt and snowpack in terms of water-equivalent (mm)
Temperature in °C
Ground-water level in well W-5-B
Snowpack depth
Average daily temperature
snowmelt
rain
0°C
7
8
Apr
May
Jun
Jul
Aug
Sep

Period 1: During this period precipitation is in the form of rain, temperature is declining, the growing season is finished and evapotranspiration is low. However, the water table is still declining and the ground water storage is depleting as discharge exceeds recharge. Infiltration from precipitation is retained mainly in the soil to bring it back to field capacity (wet limit).

Period 2: Precipitation is mainly in the form of rain, although some snow has fallen and started to accumulate on the land surface towards the end of this period. Temperature is still declining and reaches below the freezing point, however, some snowmelt occurred due to minor heat spells. Evapotranspiration is little and the infiltrated water percolates to the ground water storage, resulting in a steady rise of the water table and indicating that recharge exceeds discharge. Note that the rain event that occurred on November 1, 1969, resulted in an immedite ground water response. Later, the rise of the water table in response to the rain and snowmelt event of December 11, 1970, continued till December 22, 1970. This indicates that the percolation process of excess water from the soil to the water table is slow and continued for approximately 11 days after its start.

Period 3: During this period precipitation is in the form of snow and the depth of the snowpack is increasing. Temperature is below the freezing point and evaporation from the snowpack is minimal. The recharge to the ground water is almost nil and the ground water storage is depleting as the streamflow is made up basically of ground water discharge. Conditions which prevailed during this period provide an excellent opportunity to estimate the mean storage coefficient of the ground water domain in a basin, using the following equation:

$$R - D = S \times dH \qquad (1)$$

where:

- R = ground water recharge to the basin,
- D = ground water discharge from the basin,
- S = mean storage coefficient of the basin,
- dH = mean change of ground water levels in the basin.

During this period of interest, R=0; D=streamflow and dH is known; therefore, S can be estimated.

Period 4: A sudden rise in temperature results in precipitation falling in the form of rain and in partial melting of snow. Percolating water recharges the ground water storage and the water table starts to rise. A lagtime of approximately 9 days separates the last precipitation event and the end of the percolation process.

Period 5: During this period temperature falls again below the freezing point and precipitation is in the form of snow. The snowpack starts to grow again. Recharge is practically nil and discharge as baseflow results in a declining water table and a depletion of the ground water storage. Again, this is an ideal period to estimate the mean storage coefficient of the ground water domain.

Period 6: This period represents an isolated event when rain falls and some snow melts due to a rise in temperature. Recharge to ground water results in a continuous rise in the water table for 10 days after the precipitation event ends.

Period 7: During this period temperature starts to rise, signalling the arrival of spring. The snowpack, with exception of a few instances, is sharply depleting, until it vanishes completely by April 15, 1970. A vast amount of liquid water is suddenly available in the basin. Part of this water generates high flows and floods. The remaining water infiltrates through the soil and then percolates to the ground water storage. This is the period of major ground water recharge when the water table reaches a maximum height and the ground water storage is at a peak. In addition, evapotranspiration is insignificant because temperature is still on the low side and plant growth is minimal.

Period 8: This is a period of high evaportranspiration due to plant growth and high temperature. Precipitation is in the form of rain and a considerable part of it is held in the soil to satisfy an increasing soil moisture deficiency. Therefore, the percolation process to the ground water storage occurs only during large storms when the field capacity (wet limit) of the soil is exceeded. In general, however, the water table is steadily declining as discahrge exceeds recharge.

From the above-mentioned example, it becomes clear that the energy supply, with temperature as an index, controls the type of precipitation, the snowpack accumulation and melt, the plant growth, the evapotranspiration process and consequently the status of moisture in the soil. In the meantime, the ground water recharge, discharge and storage are affected by the type and amount of precipitation and are closely controlled by the availability of moisture in the soil.

A quantitative assessment on a monthly basis of various components of the hydrologic cycle, including the resulting ground water recharge, storage change and discharge within sub-basin W-2 in the Wilmot Creek basin, is given in Table 8 for the water year 1969-1970.

The Hydrologic Budget Equation

For a given period of time and for a particular basin, precipitation is the only water gain to the basin, provided that the basin is not gaining additional water through subsurface underflow. This water gain is balanced by water losses through evapotranspiration, runoff and changes in the soil moisture and ground water storages.

A quantitative statement of the balance between the total water gains and losses in a basin for a period of time is called the hydrologic budget. Stated as an equation, the hydrologic budget is,

$$P = R + ET \pm U \pm dS_s \pm dS_g \qquad (2)$$

where:

P = Precipitation,
R = Runoff,
ET = Evapotranspiration,
U = Subsurface underflows,
dS_s = Change in soil moisture storage,
dS_g = Change in ground water storage.

In the following paragraphs, five components - precipitation, soil moisture, evapotranspiration, surface runoff and ground water are discussed and the results are summarized in hydrologic budgets.

Precipitation

Precipitation, mainly in the form of rain and snow, is the primary source of water in the Bowmanville, Soper and Wilmot creeks basin.

As indicated previously, precipitation data are collected at nine stations within the report area (Table 3).

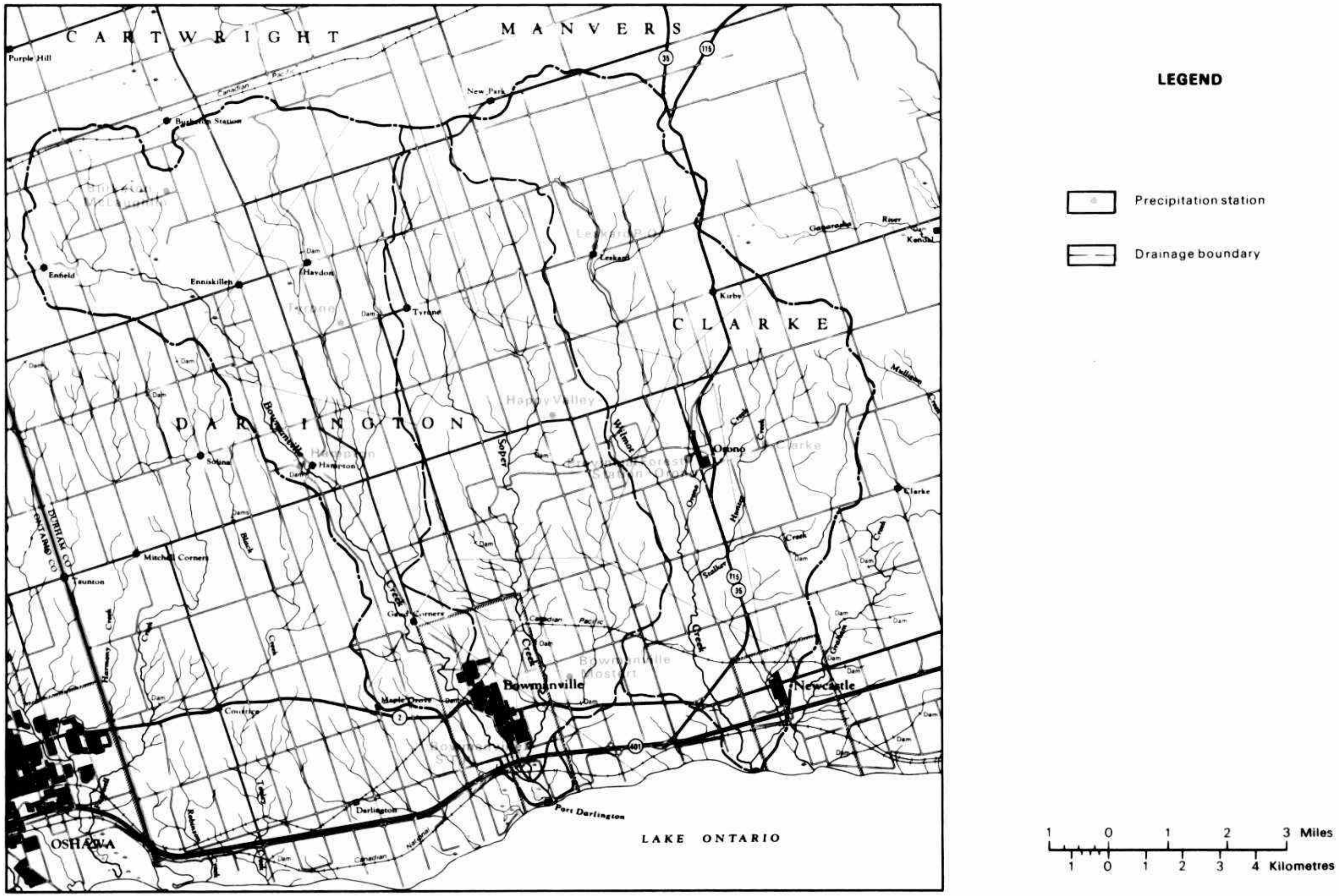


Figure 10. Location of precipitation stations and their associated Thiessen polygons.

Over 50 years of daily precipitation records are available for the Orono station. The remaining stations, however, were established more recently for the purpose of the IHD program and their records are less than 10 years long. Concurrent precipitation records with a few exceptions, are available for the nine precipitation stations from January, 1968, to March 31, 1978.

In this study, all concurrent records of the nine stations were assumed to be representative and were given the same weight as far as accuracy is concerned, regardless of the type of gauge in which data were collected.

In order to arrive at basin precipitation estimates on a monthly and annual basis, two methods were used, namely, the arithmetic mean method and the Thiessen polygon method. Figure 10 shows the location of the nine precipitation stations and their associated Thiessen polgons. Tables 9 and 10 give the areal distribution and the weights of the nine stations for the Thiessen network by basin and sub-basin, respectively.

Monthly and Annual Variation of Precipitation

In general, precipitation within the study area differs from one location to another and from one year to another. These differences reflect variations in topography, proximity to Lake Ontario, prevailing winds and the nature and frequency of the weather systems which cross the study area.

Table 11 gives the monthly and annual precipitation amounts and the 6-year (1968-1973) monthly and annual means as recorded at the nine precipitation stations. In addition, the minimum and maximum monthly and annual values are indicated in the table.

A comparison between the recorded monthly and annual values at the nine stations reveals the existence of substantial differences among various stations. The most striking example of these differences is the recorded annual precipitation at the nine stations for the year 1972. Table 11 shows that all the stations, with the exception of

McLaughlin, registered a maximum annual precipitation during the year 1972. However, the range of this maximum varied from 854 mm recorded at the Bowmanville STP station to 1083 mm recorded at the Tyrone station. The magnitude of this range (229 mm) amounts to 21-27% of the annual precipitation at these two stations for the year 1972 and might lead, if overlooked, to erroneous results in water budget calculations. This same fact, also makes the application, calibration and verification of watershed models a difficult task.

The large variations in the monthly and annual amounts of precipitation, as recorded at the nine stations, are the result of the dependence of the precipitation process on many factors, such as the latitude, the distance from a moisture source, orography of the region and the prevailing circulation patterns. As Linsley et al (1958) indicate, it is practically impossible to estimate the relative effectiveness of such factors in most analyses of the precipitation distribution. The followng conclusions on the precipitation variation within the study area can be drawn, however, from comparisons of the 6-year annual means of precipitation at the nine stations (Table 11):

The existence of an orographic barrier (the Oak Ridges) exerts more influence on the long term distribution of precipitation than does the proximity to a moisture source (Lake Ontario). Regionally, precipitation increases, in general, from the south along the Lake Ontario shoreline, towards the north. The lowest 6-year annual mean was recorded at the Bowmanville STP station located at the lower end of the basin and equalled 773 mm. On the other hand, the highest 6-year annual mean was recorded at the Leskard station located in the Oak Ridges area and equalled 904 mm.

Basin and Sub-basin Precipitation

The monthly and annual precipitation amounts and their long-term means (1968-1973) for the Bownmanville, Soper and Wilmot creeks drainage basin were derived using the arithmetic mean and the Thiessen polygon methods (Table 12). The results of both these methods are in close agreement, although, the Thiessen method gives slightly higher values most of the time.

In addition, monthly and annual precipitation amounts and their long term means were computed separately for each of the three major basins within the study area (i.e. the Bowmanville Creek basin, the Soper creek basin and the Wilmot Creek basin), as well as, for all their sub-basins (Table 13). Table 13 was derived using the Thiessen polygon method and will be used in the hydrologic budget calculations for various parts of the study area. Note that the data from the McLaughlin station (Table 11) represent the precipitation in sub-basins B-1 and B-2 and that data from the Leskard station represent precipitation in sub-basins S-1, W-1 and W-2.

Snow

A complete description of the precipitation process for a Canadian basin has to include information on snow measurement, accumulation and melt.

During the winter season a considerable part of precipitation falls in the form of snow. Snow is a deposit of ice crystals which has the capacity to accumulate on the ground surface for a considerable period of time under favourable climatic conditions. This capacity of the snow to accumulate effects, to a large extent, all the hydrologic processes that take place within the study area, including recharge to and discharge from the ground water storage, for almost half of the year.

Freshly fallen snow usually has a density between 0.07 and 0.15, with an average of about 0.10 (Linsley et al, 1958). In this report, the water equivalent of newly fallen snow is computed on the assumption of a density of 0.10, a common practice in Canada.

Snow Measurements

In addition to the nine precipitation stations where the total daily snowfall is recorded in terms of inches of water equivalent, a snow sampling network consisting of twelve snow courses was established within the Wilmot Creek basin. The network density is approximately one snow course per 6.86 km^2. A standard snow

course consists of ten sampling points distributed at regular intervals of 30.5 m. The point sample observations are: snow depth, water equivalent and computed density. The tubular snow sampler used was a standard MSC Type-1 (Logan, 1972). Data on snow depth collected from the snow sampling network were used to verify the applied snowmelt procedure.

Snow Data Analysis

The total annual precipitation, snowfall in terms of millimeters of water equivalent and their ratios as measured at the nine precipitation stations for the period 1968-1973, are given in Table 14. In addition, the precipitation, snowfall and their ratios as measured during the winter seasons (1967-1973) at the nine precipitation stations, are given in Table 15. The winter season as given in Table 15 extends from November to April.

An examination of Table 14 reveals, as in the case of precipitation, the existence of substantial differences in snowfall between various stations and between various years. For example, the annual snowfall water equivalent during the year 1972 ranged from 121.2 mm recorded at the Mostert station, to 304.5 mm recorded at the Happy Valley station. In the meantime, the annual snowfall water equivalent at the Orono station, during the period 1968-1973, varied from 54.1 mm recorded in 1973 to 217.9 mm recorded in 1972.

In general, the lowest annual snowfall values are recorded at the Mostert station which is located at the southern end of the study area, whereas the highest values are recorded at the Leskard station which is located in the Oak Ridges area. This indicates that the annual snowfall increases from the south along the Lake Ontario shoreline, towards the north.

For the available period of record, the total annual snowfall water equivalent ranges from 48.8 mm, recorded at the Mostert station in 1969, to 304.5 mm recorded at the Happy Valley station in 1972. These two values represent 6 to 32% of the total annual precipitation at each station, respectively. However, if only precipitation amounts during the winter seasons were to be

considered, then the ratio of snowfall to precipitation would increase substantially. As Table 15 indicates, the lowest ratio (13%) was recorded at the Mostert station (winter season 1968-1969) and the highest ratio (60%) was recorded at the Hampton station (winter season 1970-1971).

Snowmelt

The generation of snowmelt at a point location in a snowpack is essentially a thermodynamic process, the amount of melt produced being dependent on the net heat exchange between the snowpack and its environment (Gray, 1970).

Logan (1975) developed a snowmelt model based on the energy flux and mass transfer processes which occur accross the snowpack-atmosphere interface, within the snowpack and along the snowpack-gound surface interface. The model consideres the snow accumulation, evaporation, sublimation and the snowmelt as separate but linked major processes in the simulation scheme. The model was applied to simulate the snowmelt in Wilmot Creek basin using precipitation data from the Mostert and McLaughlin stations (both being outside the basin) for the winter season 1970-1971. The results of the model were within one standard deviation from the mean snowpack water equivalent as measured at 12 snow courses located in the Wilmot Creek basin (Figure 11).

For the purpose of this study, which deals basically with the analyses of the hydrologic processes on a monthly and annual basis, a simpler snowmelt procedure was considered satisfactory.

To estimate the amount of daily snowmelt, the daily average temperature T and the daily rainfall R were chosen as snowmelt factors. The relation between the amount of daily snowmelt SM, and both these factors, was assumed to be:

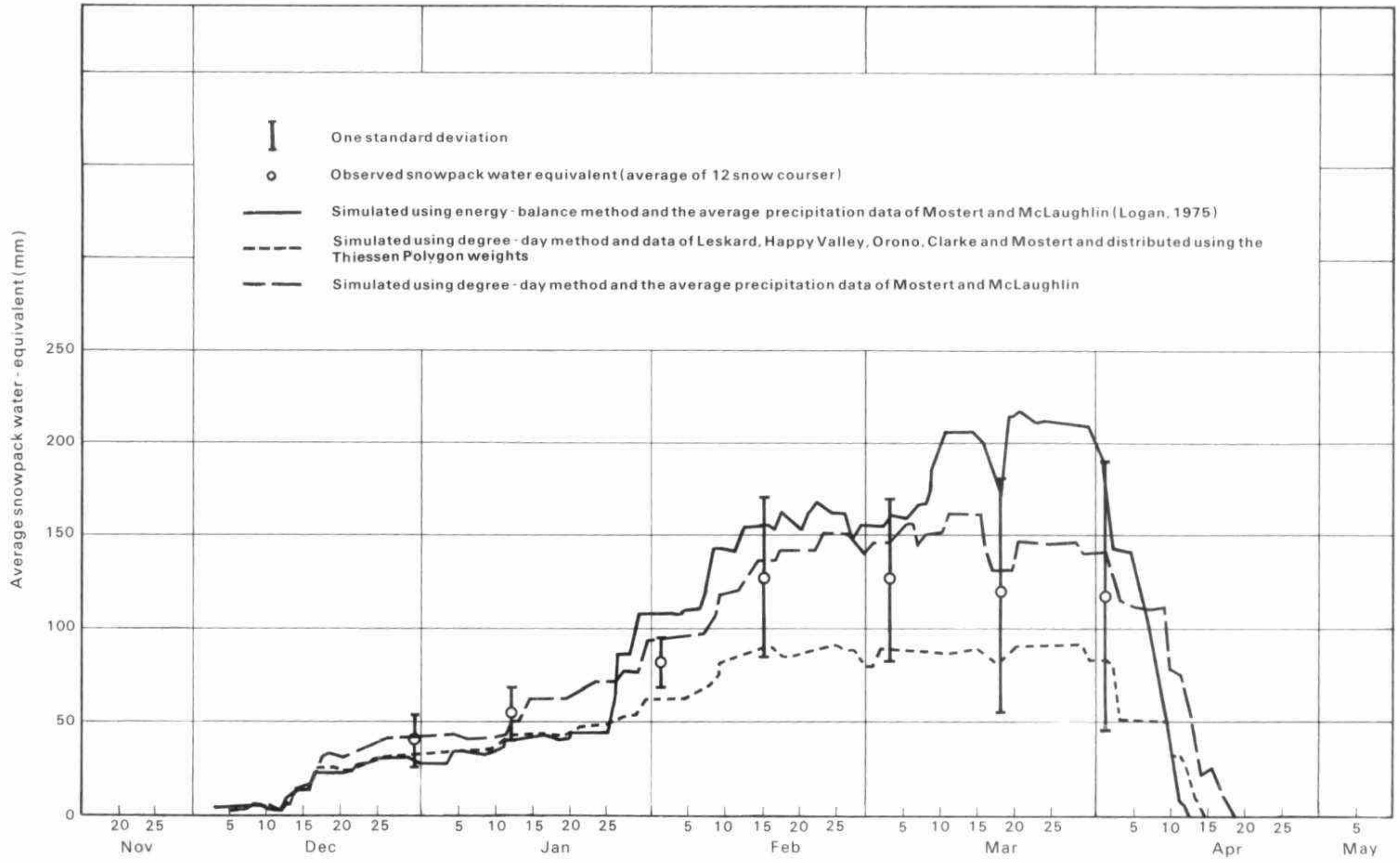


Figure 11. Simulated daily average snowpack water equivalent using the Energy - Balance method and the Degree - Day method for the winter season 1970 - 1971.

$$SM = M_T + M_R \qquad (3)$$

which can be written, also, as:

$$SM = aT + R\frac{T}{80} \qquad (4)$$

where:

SM	=	total daily snowmelt (mm);
M_T	=	daily snowmelt caused by temperature (mm);
M_R	=	daily average snowmelt caused by rain (mm);
T	=	average daily temperature (^{o}C);
a	=	a constant equal to 3 mm/^{o}C/day;
R	=	daily rainfall (mm);
80	=	the heat of fusion of ice (cal/g).

When the average daily temperature T is below the freezing point ($0^{o}C$), precipitation is assumed to fall as snow and is added to the snowpack until melting conditions occur. When T is above zero, the snowpack is assumed to release a daily amount of water M_T which is proportional to temperature according to the following relationship:

$$M_T = aT \qquad (5)$$

The constant a was estimated to be equal to 3 mm per one degree Celsius per day, by trial and error, using the streamflow hydrographs corresponding to snowmelt conditions. In addition, when T is above zero, precipitation was assumed to fall as rain and the snowpack was assumed to release an additional amount of melt water M_R which is determined from the relationship:

$$M_R = R\frac{T}{80} \qquad (6)$$

The snowmelt scheme described above is known in literature as the Degree-Day method. The simplicity of the method and the availability of the input data (temperature and precipitation) constitute a great advantage. However, one should recognize that air temperature and rain are only two approximate indices of the net heat exchange between the snowpack and its environment. Hence, it is important to compare the results of this method with the results of a more elaborate method based on the heat balance approach, using the same data.

As was mentioned above, Logan (1975) simulated the snowmelt in the Wilmot Creek basin during the winter season 1970-1971, using a mathematical model based on the net heat exchange between the snowpack and its environment. Logan assumed that the average precipitation at Mostert and McLaughlin stations located outside the basin is representative of the basin precipitation. For comparison purposes, the same data were utilized to simulate the snowmelt in Wilmot Creek basin using the Degree-Day method. Figure 11 shows the daily snowpack depth in terms of millimeters of water equivalent, as reported by Logan (solid line) and as calculated from the Degree-Day method (dotted line). As can be seen from the Figure both methods gave identical results during the first 50 days of simulation. Starting on January 26, 1971, however, the results from both methods went along two different paths, yet remaining within one standard deviation from the average snowpack depth as measured at 12 snow courses in the Wilmot Creek basin. The Energy-Balance method gave higher values than the observed average, whereas the Degree-Day method gave lower values than the observed average.

In order to test further the validity of the Degree-Day method, an additional analysis was considered necessary, because Mostert and McLaughlin stations are both outside the Wilmot Creek basin. The additional analysis used more precipitation data to cover the basin of interest appropriately. Table 10 indicates that precipitation in the Wilmot Creek basin should be computed from precipitation data at the following stations: Mostert, Leskard, Happy Valley, Orono and Clarke, with Thiessen weights of 0.016, 0.402, 0.078, 0.192, and 0.312, respectively. Daily precipitation data at these five

stations for the winter season 1970-1971 were utilized to simulate the snowmelt at each site using the Degree-Day method and the results were multiplied by Thiessen weights and summed to determine the snowmelt in the Wilmot Creek basin. Figure 11 shows the simulated daily average snowpack depth in terms of millimeters of water equivalent obtained from the five stations using their Thiessen weights (broken line). It can be seen from the Figure that the computed snowpack water equivalent using precipitation data from the five stations is in close agreement with the observed average snowpack, as measured at 12 snow courses in the Wilmot Creek basin.

From the foregoing it is possible to conclude that the Degree-Day method, despite its approximate nature, gives surprisingly good results.

The Degree-Day method was applied to the available records at the nine precipitation stations in the study area. Table 16 gives summaries of the results which include for each station estimates of the snow storage at the beginning and the end of each month, the amount of snowmelt and the water input to the basin (rain and snowmelt) during the month. It is evident from these tables that the snowfall, snow accumulation and snowmelt have a great modifying effect on the preciptitation input to the study area. The timing and magnitude of this effect differ from one year to another and from one location to another, reaching in some years tremendous proportions.

It is possible to conclude, based on Table 16, that the amount of rainfall and snowmelt during the months of November, December, January, February and, sometimes, March is less than the precipitation input. On the other hand, during the months of March and frequently April the sum of rainfall and snowmelt is much larger than the precipitation input. The large volume of water that is released during March and April, generates high flows and sometimes floods and contributes substantially to the ground water storage through recharge. It is possible to state, therefore, that the major period of ground water recharge in the study area, coincides closely with the snowmelt period.

Table 17 gives the monthly and annual modified precipitation input due to snow accumulation and melt as computed from the Thiessen polygon network for various basins and sub-basins in the study area. Values from Table 17 will be used in the computation of the monthly and annual hydrologic budgets as well as in the estimation of the monthly and annual ground water recharge.

Soil Moisture

General Definitions

Soil is that part of the earth's crust which is penetrated by the roots of plants and has been developed through the operation of various climatic factors on rocks and overburden (parent materials) and modified by vegetation, relief, drainage and use.

Every soil consists of various mixtures of gravel, sand, silt, clay and organic matter and can be classified according to the proportions of these substances. A soil that has a moderate amount of sand (30-50%), silt (30-50%) and clay (0-20%), is called loam.

Davis and Bennett (1927) have outlined a system of classification which has become widely recognized that is based on three basic soil classes: sand, loam and clay. By using the term silt in various combinations with these three soil classes, the possible number of principal soil classes was increased to ten.

The soil from the viewpoint of hydrology acts as a reservoir; at any time there is some water in storage in the soil referred to as the soil moisture. Water in the soil can be classfied as:

1. Hygroscopic water which is that part of the soil moisture that is absorbed from the atmosphere as a thin film on the surface of soil particles, held with considerable force, and not available to plants.

2. Capillary water which is that part of the soil moisture that is held by surface tension in the capillary spaces and as a continuous film around the particles, free to move under the influence of capillary forces, and available to plants.

3. Gravitational water which is that part of the soil moisture that drains through the soil under the influence of gravity (Linsley et al, 1958).

Two concepts are often used with regard to soil moisture - the field capacity and the wilting point. The field capacity is the amount of moisture remaining in the soil after the gravity water has been allowed to drain away, usually expressed as a percentage of the oven-dry weight of soil. The wilting point, on the other hand, is the moisture content of soil, on an oven-dry basis, at which plants wilt and fail to recover their turgidity when placed in a dark humid atmosphere (Stefferud, 1957). Recently, The terms field capacity and wilting point are being phased out. Instead, the terms wet limit and dry limit are used. These two limits are given as percentages of the volumetric moisture content at 0.33 - bar and 15 - bar, respectively. The quantity of water a soil can retain in a form available to plants is between the limits 0.33 bar percentage, the wet limit, and 15 - bar percentage, the dry limit.

Soil Series, Types and Phases in the Study Area

Webber and Morwick (1946) classified the soils in the study area in terms of series, types and phases. The term soil series was used to designate a group of soils whose profiles are alike with regard to their general character and appearance and which were developed from similar parent materials. They are usually given a geographical name from a town, village, township, etc. The term soil type was used to describe the textural composition of the soil (sand, loam, clay). Finally, the term soil phase refers to all the variations that occur in a soil series other than texture, such as stoniness, shallowness, topography, drainage and erosion.

Nineteen classes of soils are present within the study area based on the soil map of Durham County published by Webber et al (1946). Eight of these classes developed on till and range in texture from that of loam to sandy loam. Two classes developed on glacio-fluvial material and range in texture from sandy loam to sand. Five classes developed on deltaic or outwash deposits and range in texture from sandy loam to sand. Three classes developed on lacustrine deposits and range in texture from clay loam to loam. Finally, one class has an organic origin and is made up of muck. From the foregoing, it is clear that these nineteen soil classes reflect the surficial geology of the study area. Table 18 gives the names, symbols, parent material, description of surface and subsoil materials, and drainage properties of various types of soils within the study area, based on the soil map of Durham County. In addition, the Table includes estimates of the dry limit (15-bar) and the wet limit (0.33 - bar) in percentages of volumetric moisture content as given by Webber and Tel in an unpublished report entitled: "Available Moisture in Ontario Soils, 1966".

Soil Moisture Measurements in the Study Area

Soil moisture was measured at 15 sites within the study area (Figure 3). Three holes were drilled at each site to a depth of 1.5 m and they were equipped with aluminum tubing, 38 mm in diameter. A neutron scattering meter was used in moisture measurements and the periodic changes of moisture profile were obtained by converting the scaler readings into percentages of moisture by volume.

Neutron measurements were taken in the field every 10 to 35 days during the spring, summer and fall, since the month of April, 1969.

Role of Soil Moisture in the Hydrologic Cycle

The zone of soil moisture is at critical juncture in the hydrologic cycle. From the initial impact of precipitation on the soil surfce to the final drainage or evaporation of water from the soil, it presents many facets. Thus, the infiltration process, the storage of water within the soil profile, the transmission of water laterally as interflow or vertically as ground water recharge, the evaporation of the stored soil moisture or its utilization by the plants, and the freezing-thawing cycles, are all facets of the role that soil moisture plays.

Precipitation is the primary source of water for the soil moisture recharge whereas the lateral transfer of water over the ground surface from topographic highs to lows, and the upflow of water from the ground water zone to unsaturated zone provide further sources for recharge of soil moisture.

The primary mechanisms for soil moisture depletion are through evapotranspiration and gravity drainage. The magnitude of evapotranspiration is controlled by the soil moisture availability and the climatic conditions. Gravity drainage, on the other hand, occurs in response to pressure gradients either vertically or laterally. Whereas the lateral movement of the soil moisture generates interflow, the downward vertical movement of the soil moisture to the saturated zone contributes to ground water recharge.

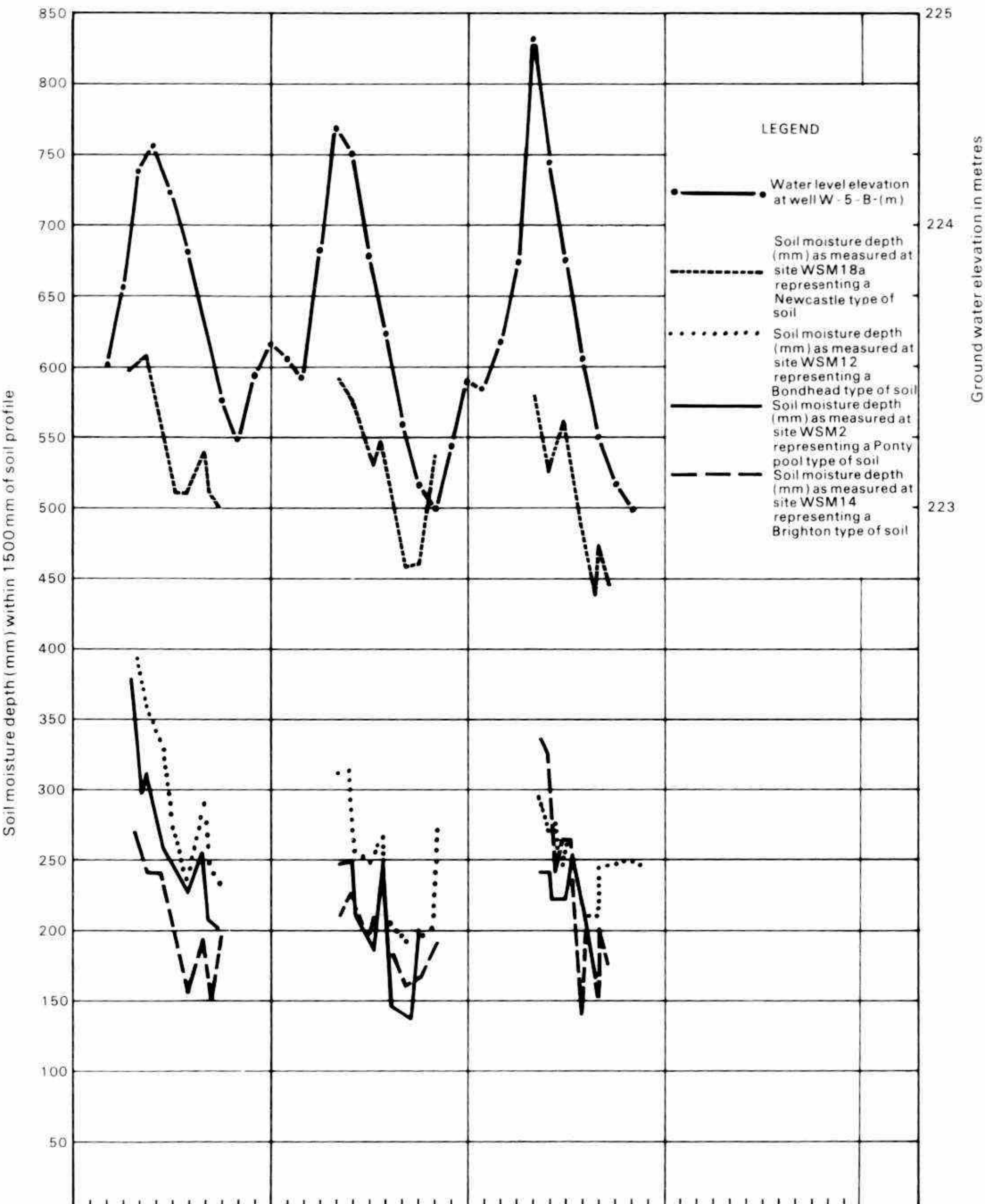


Figure 12. Comparison between ground water level variations as measured at well W - 5 - B and soil moisture depth variations within 1.50m of soil profile as measured at sites: WSM2, WSM12, WSM14 and WSM18a.

The process of ground water recharge within a basin is completely controlled by the status of moisture in the soil, provided that there is no gain to the ground water storage from outside the basin. Recharge to ground water will occur at a maximum rate when the soil is in a state of complete saturation and diminishes when the soil is at the wet limit (field capacity). Within the study area, this condition is met mainly during the snowmelt period in the spring or during limited heat spells in the winter and, also, late in the fall. During the summer period the soil moisture is utilized mainly by the plants and a state of soil moisture deficiency usually prevails. Therefore, most of the infiltrated water from the rain, during this period, is used to satisfy this deficiency with little or no water left to recharge the ground water.

Figure 12 gives a comparison between the ground water level variations as measured at well W-5-B (sandy till aquifer) and the soil moisture depth variations in millmeters within the top 1.5 m of soil profile as measured at sites: WSM2, WSM12, WSM14 and WSM18a. These sites are representative of Pontypool, Bondhead, Brighton and Newcastle types of soil, respectively. As can be seen from the Figure, the soil moisture content is highest during the spring, recedes during the summer and recovers during the fall. This is analogous to the ground water level variations.

Evapotranspiration

Evapotranspiration is the combined evapotranspiration from water, snow and soil surfaces and transpiration by vegetation (Linsley et al, 1958). When the supply of water is non-limiting, evapotranspiration occurs at the potential rate. If the water supply is limited, actual evapotranspiration will fall short of potential evapotranspiration.

Estimates of monthly and annual potential evapotranspiration within the study area were made using the method of Thornthwaite (1948) and are listed in Table 19. The Thornthwaite method employs an empirical equation which relates the potential evapotranspiration to the mean air temperature and includes a latitude adjustment factor which varies with the latitude of the station and has a different value for each month of the year at a given location.

The mean monthly temperatures as measured at the Orono station were assumed to represent the temperature variations within the study area and were used to obtain the monthly values of potential evapotranspiration.

Table 19 indicates that the annual potential evapotranspiration within the study area during the period 1968-1973 ranged from 536.2 to 597.4 mm with an annual mean of 574.2 mm.

The monthly precipitation amounts as computed using the Thiessen polygon network for each basin and sub-basin within the study area, along with the estimated monthly potential evapotranspiration values, were used as input to Holmes and Robertson (1960) moisture budget technique to arrive at the actual monthly evapotranspiration. In order to carry out the analysis, two additional types of data are required: an estimate of the initial soil moisture storage values for the first month to be analyzed and an estimate of the soil moisture capacity within each basin.

It was assumed that the initial soil moisture storage for the first month to be analyzed (January) is equal to the soil moisture capacity for the basin. The soil moisture capacity for the basin was estimated using the following procedure:

i - The area of each type of soil within the basin of interest was determined;

ii - The areal weight for each type of soil was calculated by dividing the area of each type of soil by the area of the basin;

iii- The maximum available moisture for actual evapotranspiration was assumed to be equal to the difference between the wet and dry limits percentages (Table 18) multiplied by the soil profile depth. The computation was made on the basis of a soil profile depth of 1 m;

iv - The weights of soil moisture capacity for each type of soil were determined by multiplying the areal weight of each soil by its maximum available moisture;

v - The weights of various soil moisture capacities of all the soils in a basin were summed to arrive at soil moisture capacity for the basin.

Tables 20, 21 and 22 give the areal distribution of various types of soils for each basin and sub-basin within the study area. In addition, these tables include the areal weights of various soils, their contribution to the soil moisture capacity of the basin and finally, the sum of these contributions which constitutes an estimate of the soil moisture capacity for each basin and sub-basin in the study area.

The estimated soil moisture capacities according to the above-described procedure, range from 92.22 to 184.53 mm, which is similar to the range suggested by the Canada Department of Agriculture (1956). Their measured values were:

sandy loam:	106.68 mm
loam and silty loam:	157.48 mm
clay loam and clay silty loam:	182.88 mm
clay and silty clay:	198.12 mm

Estimates of the monthly and annual actual evapotranspiration for the period 1968-1973 and the 6-year annual means by basin and sub-basin are given in Table 23. The table indicates that most of the actual evapotranspiration occurs during the period May-September with minor actual evapotranspiration during April, October and November and little or none in the rest of the year.

The 6-year annual means of actual evapotranspiration for different basins and sub-basins in the study area range from 443.6 to 507.9 mm which is in good agreement with the 6-year means of annual losses (actual evapotranspiration $\pm$ changes in soil moisture and ground water storages) that range from 433.4 mm to 560 mm.

Streamflow

General Description

Streamflow from the Bowmanville, Soper and Wilmot creeks drinage basin is typical of most basins in the Province of Ontario where the primary source of flow is snowmelt and ground water discharge.

As was described earlier, precipitation during the winter season is mainly in the form of snow which accumulates on the ground surface as a snowpack. Therefore, the streamflow is maintained during the winter to a large extent by the ground water which seeps through the streambeds as baseflow, resulting in low flow conditions during this period.

Water stored in the snowpack becomes available for surface runoff and ground water recharge as the daily temperature rises during the spring season and the snowpack melts. Snowmelt produces a large quantity of water which generates high flows and occasional floods.

During the summer season, the evapotranspiration demands become high and most of the rain is utilized to satisfy the soil moisture deficiency. Hence, the streamflow is maintained again by the ground water discharge and only localized, high intensity storms produce any significant contribution to streamflow.

As the evapotranspiration demands decrease during the fall season and the soil moisture is restored to field capacity, the incoming rain produces moderately high streamflows and contributes at the same time to ground water recharge.

From the foregoing, it is possible to describe the runoff process in the study area, on a seasonal basis, as being a two peak, two recession process. The two peaks occur during the spring and the fall, with the first being high and the second being moderate. The two recessions occur during the winter and summer, with the first being short lived (December-February) and moderate and the second longer lived (May-September) and steep.

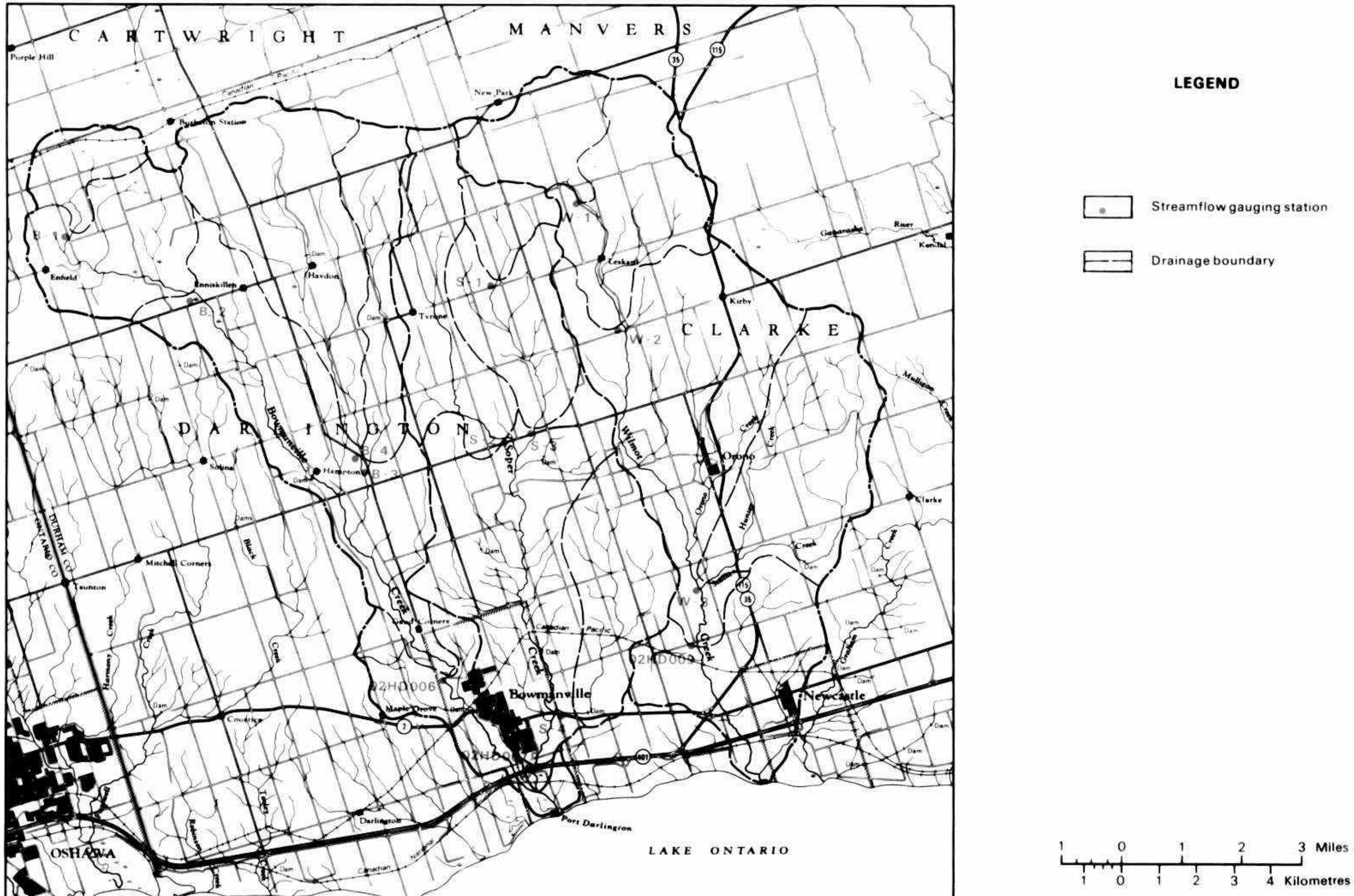


Figure 13. Locations of streamflow gauging stations and their drainage boundaries in the Bowmanville, Soper and Wilmot creeks drainage basin .

Streamflow Measurements

Table 24 lists the names, numbers, drainage areas, locations, periods of records and quality of records of all the streamflow gauging stations in the study area. In addition, Figure 13 shows the locations of these stations and their drainage boundaries. All these stations, with the exception of the federal gauges on the Bowmanville, Soper and Wilmot creeks, were established for the IHD program and were maintained by the Ministry of the Environment.

Concurrent daily streamflow data, with a few exceptions, are available for most of the gauging stations since January 1968. These data indicate that the Bowmanville, Soper and Wilmot creeks and their major tributaries are perennial streams. However, the majority of the secondary order tributaries are intermittent streams.

In general, daily streamflow records collected at most of the gauging stations in the study area during the spring-fall period are fair to good in quality; however, streamflow data collected during the winter season range in quality from extremely poor to fair. This is due to ice conditions which prevail during the winter and necessitate ice corrections that are in most cases subjective and sometimes extremely difficult to make.

The double mass curve method was used to check the consistency of the streamflow data as recorded at each gauging station in the study area. Each of the stations' cumulative flows were plotted against the cumulative mean flow of all the stations in the study area which was assumed to represent the flow pattern. The method revealed significant inconsistancies at stations: B-1 at Enfield, B-3 at Hampton and 02HD006 at Bowmanville. No attempt was made to adjust the streamflow records at these three stations and they were not used in any further analyses.

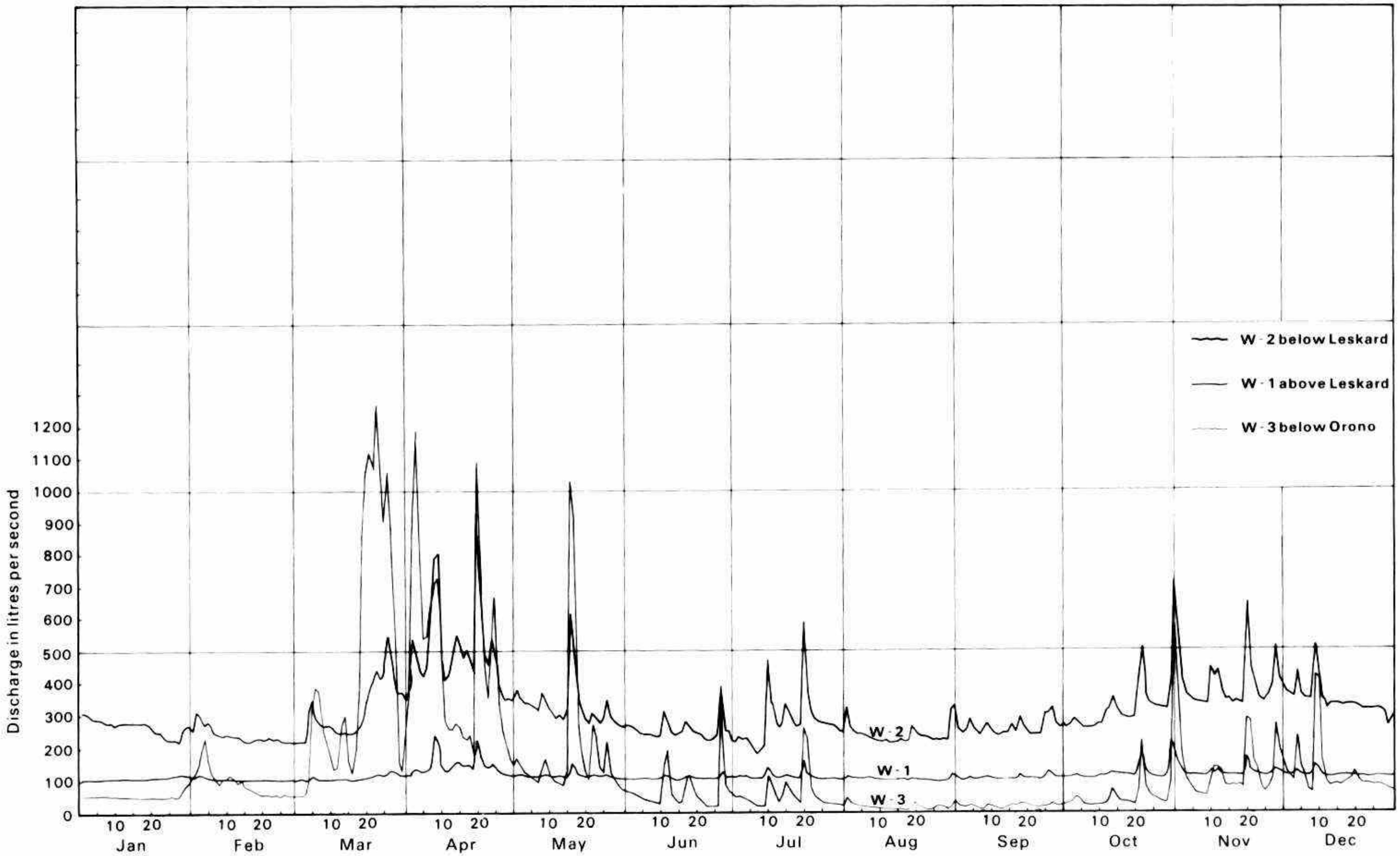


Figure 14. Daily streamflow hydrographs as recorded at stations: W - 1, W - 2 and W - 3 for the year 1970.

Variability of Streamflows

Mean, Maximum and Minimum Daily Flows

Hydrographs of mean daily flows are presented in Figure 14 to show the variability of streamflows in the Wilmot Creek basin. The hydrographs are for gauging stations: W-1, W-2 and W-3 for the year 1970, which represent flows in the upper, middle and lower parts of the Wilmot Creek basin, respectively. The Figure shows the relative magnitude of streamflow occurring simultaneously at each site and the similarity in the pattern of streamflow where most of the peaks and recessions coincide.

The figure indicates that highest daily flows occurred during the March-May period as a result of the snowmelt process. Other high flows occurred after severe summer and fall rainstorms during the months of July, October, November and early December. Lowest flows occurred during the winter months of January and February as well as during the summer months of June, August and September.

A closer examination of Figure 14, however, reveals the existence of significant differences among the flow regimes at the three gauging stations. On one hand, the daily streamflows at station W-1 seem to vary little from one day to the next. The daily flows at this station during the year 1970 averaged 0.119 m^3/s and ranged between a maximum flow of 0.249 m^3/s (April, 8) and a minimum flow of 0.099 m^3/s (August, 18), with a maximum to minimum flow ratio of 2.52. On the other hand, significant variations in daily flows are observed at station W-3. The daily flows at this station during the same period averaged 0.150 m^3/s and ranged between a maximum flow of 1.291 m^3/s (March, 23) and a minimum flow of 0.011 m^3/s (August, 11), with a maximum to minimum flow ratio of 117. The variability of daily flows at station W-2 is between the above-described two extreme cases. The daily flows at W-2 during 1970 averaged 0.323 m^3/s and ranged between a maximum flow of 0.949 m^3/s (April, 20) and a minimum flow of 0.190 m^3/s (July, 7) with a maximum to minimum flow ratio of 4.99.

The differences between the flow regimes in sub-basins W-1 and W-3 are due to differences in physiography which encompasses the interactions between geologic and climatic factors. Sub-basin W-1 is located within the Oak Ridges physiographic unit. The surficial geology is made up mainly of glacio-fluvial deposits which consist of sand and gravel material up to 100 m in thickness. The topography of the sub-basin is characterized by hilly, irregular surfaces, and it is marked by knolls and closed depressions with virtually no surface drainage network. Rain and snowmelt infiltrates easily into the sandy loam soil which covers over 70 percent of this sub-basin. Water percolates downward to the water table whenever the soil moisture is above field capacity. The most significant hydrologic processess under these physiographic conditions are: precipitation, infiltration, evapotranspiration, ground water recharge (percolation) and ground water discharge. The direct surface runoff component is not significant and as such, the streamflow is made up basically of ground water discharge (baseflow).

The physiography of sub-basin W-3 is completely different from that of sub-basin W-1. The upper, northeastern portion of sub-basin W-3 is a part of the Till Plain physiographic unit, whereas its lower, southwestern portion is a part of the Iroquois Plain physiographic unit. The surficial geology of the sub-basin is made up of flavial deposits (till) and glacio-lacustrine deposits (sands, silts and clay). The topography varies from gentle to fairly steep and the drainage network is well developed. Rain and snowmelt infiltrates into the loam to sandy loam soils; however, it can not percolate easily through the underlying till deposits which have a low vertical hydraulic conductivity coefficient. Therefore, the excess water flows over the land, creating a significant direct runoff component. Under these physiographic conditions, the most significant hydrologic processes are: precipitation, infiltration, evapotranspiration and direct runoff. The ground water recharge is small and consequently the ground water component in the streamflow is not significant. Therefore, the wet periods are characterized by large flows and the dry periods are characterized by extremely low flows which are relesed from a limited ground water storage.

The flow regimes of the remaining eight sub-basins under consideration are either similar to the flow regime in sub-basin W-1 or similar to the flow regime in sub-basin W-3 or somewhere in between these two extremes. Table 25 gives the mean, maximum and minimum daily flows and their dates of occurrence, as well as the maximum to minimum daily flow ratios for various basins and sub-basins in the study area. The table indicates that maximum daily flows occur most frequently during the months of March and April, whereas the minimum daily flows occur most frequently during the months of June, July, August and September. The total water withdrawal from the Bowmanville, Soper and Wilmot creeks drainage basin is approximately 11,000 m^3/day which has little or no effect on the flow regime (Funk, 1977).

If one assumes that the ratio of the maximum to minimum daily flows is an index of the significance of the ground water component in the streamflow, then the sub-basins under study could be arranged in the following order: W-1, W-2, S-1, B-4, S-3, S-2, B-2, W-3 and S-4, with W-1 having the most significant ground water component. The long term means of maximum to minimum daily flow ratios at these sub-basins are: 4, 7, 18, 22, 28, 42, 44, 390 and 421, respectively. Sub-basins with small ratios are characterizied by a significant ground water component in their hydrologic budgets. These sub-basins are either located completely within the Oak Ridges physiographic unit (W-1) or they contain, in addition, a part of the Till Plain physiographic unit (W-2, S-1, B-4, S-3, S-2, B-2). The last two sub-basins, namely, W-3 and S-4 drain portions of the Till Plain and Iroquois Plain physiographic units; their hydrologic budgets contain a small ground water component.

Monthly, Annual and Long Term Means of Surface Runoff

Table 26 gives the monthly, annual and long term monthly and annual total runoff for various basins and sub-basins in the study area for the period 1968-1973.

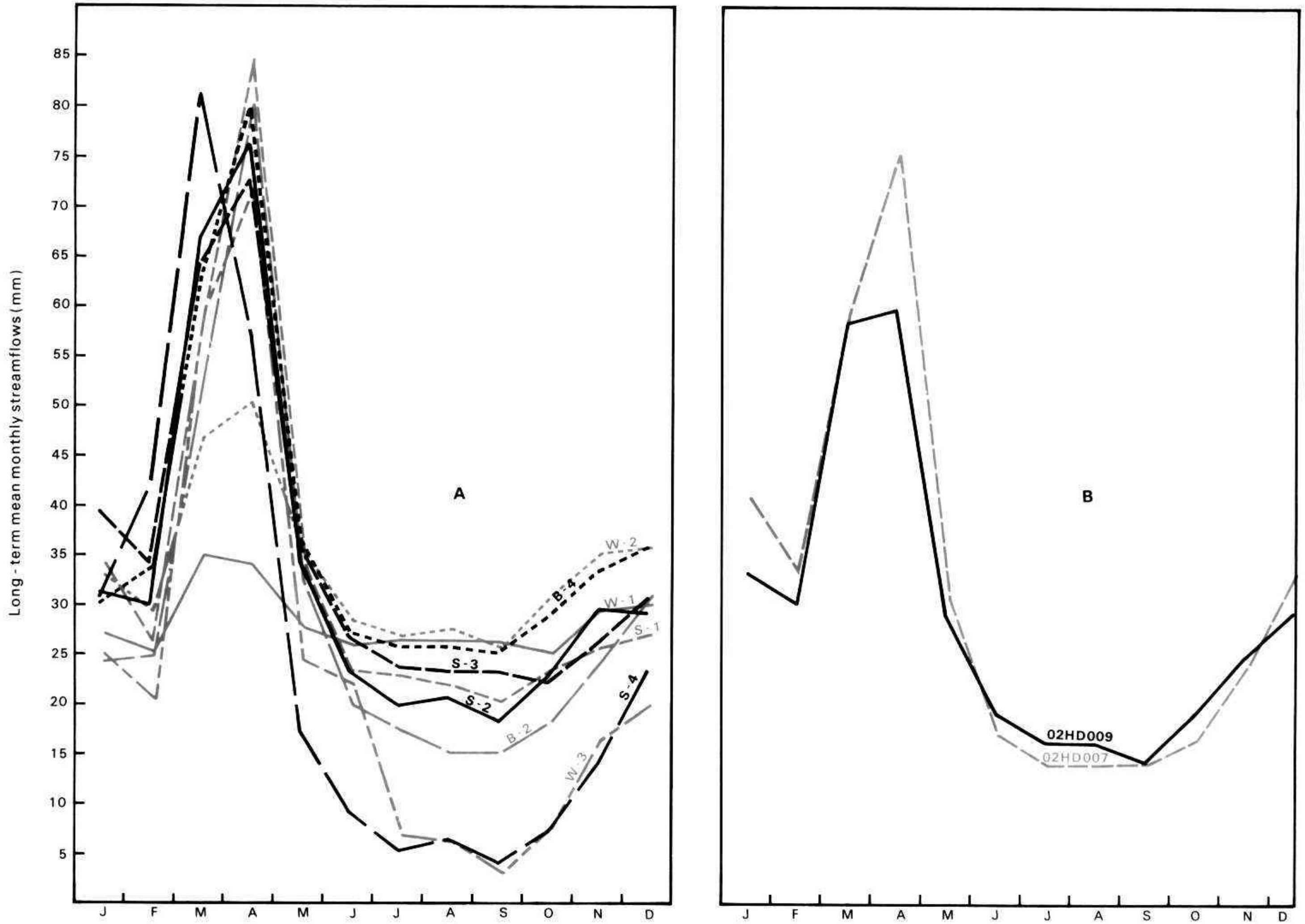


Figure 15. (A, B). The runoff pattern in the Bowmanville, Soper and Wilmot creeks drainage basin based on long term monthly means of flows as measured at various gauging stations in the study area.

Monthly flows at all the stations exhibit, in general, the following pattern: a relative decline from January to February, a substantial rise during March and April, a continuous decline from May to September and a relative rise from October to December.

The long term means of monthly flow at various stations represent an index of the flow patterns for different parts of the study area. Table 26 indicates that the maximum long term monthly means occur at most stations during the month of April whereas the minimums occur during the month of September.

Figure 15 gives the hydrographs of the long term means of monthly runoffs for various basins and sub-basins in the study area. The figure reveals that the hydrographs of all the stations are similar in terms of the nature of the changes of flow. When the relative magnitudes of these changes are considered, however, the figure indicates the existence of three different flow patterns. One flow pattern is observed at station W-1, whose hydrograph is characterized by a gentle rise during the period March-April, a flat recession during the period May-October and a moderate rise during the period November-December.

A second flow pattern is observed at stations W-3 and S-4. The hydrographs of long term means of monthly runoffs at both stations show sharp peaks during the period March-April, steep recessions during the period May-July and substantial rises during the period October-December. The third type of flow pattern is mixed and is exhibited by the hydrographs of all the other gauging stations. The best representations of this third flow pattern are the hydrographs of long term means of monthly flows of the federal stations 02HD007 (Soper Creek) and 02HD009 (Wilmot Creek). Both these streams drain portions of the Oak Ridges, the Till Plain and the Iroquois Plain physiographic units, and their flow patterns exhibit the combined effects of the three physiographic units.

The maximum total annual flows were observed at most stations during the year 1972 and the minimum flows were observed during the year 1970. These were also the years of maximum and minimum annual precipitation, respectively.

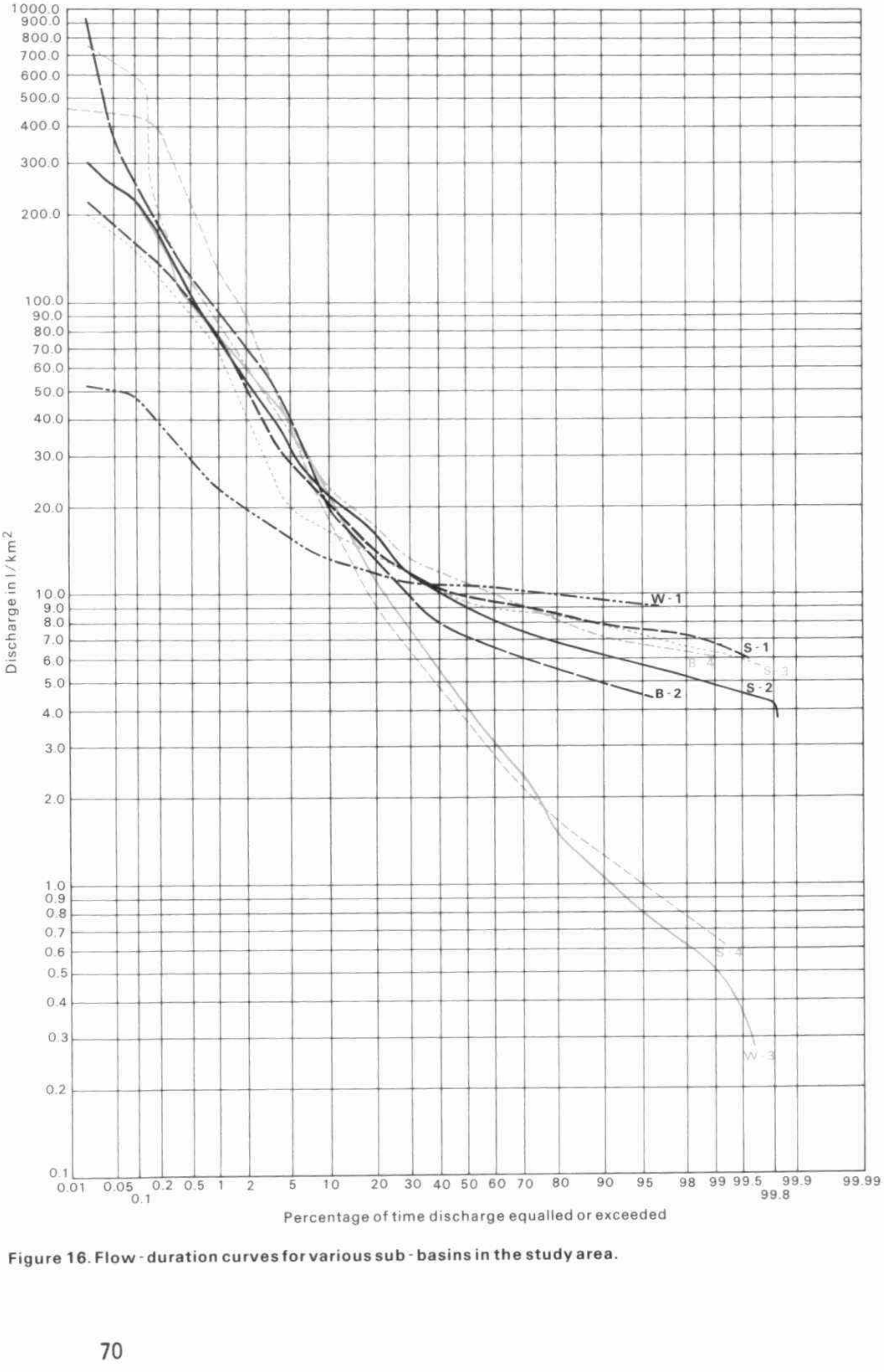


Figure 16. Flow - duration curves for various sub - basins in the study area.

The gauging stations under consideration can be arranged in terms of decreasing long term means of annual runoff in the following order: B-4, S-3, W-2, S-1, S-2, 02HD007, 02HD009, W-1, S-4 and W-3. The long term means of annual runoff at these stations in mm are: 446.3, 434.5, 408.6, 407.4, 402.1, 367.8, 350.2, 344.4, 298.7 and 276.2, respectively. This indicates, that the annual yield of total surface runoff from sub-basins W-1, S-4 and W-3 is the least in comparison with the other basins and sub-basins in the study area. On the other hand, sub-basins which include portions of the Oak Ridges and the Till Plain physiographic units have the highest annual yield. In these sub-basins, the processes of ground water recharge, discharge and direct surface water runoff are all important. Whereas, in the case of sub-basin W-1, only ground water recharge and discharge are important in the generation of surface runoff; in the case of sub-basins W-3 and S-4, only the direct surface runoff component is prominent in the generation of surface runoff.

Flow-Duration Analyses

Flow duration curves are cumulative frequency curves indicating the percentage of time a given flow has been equalled or exceeded during the period of record; they are one measure of flow variability. Flow duration curves for various sub-basins in the study area are shown in Figure 16.

The shape of the flow duration curve is determined by the hydrologic and geologic characteristics of the drainage basin. The more nearly horizontal the curve, the greater is the role of ground water discharge in sustaining the streamflow. Thus the shape of the flow duration curve is an index of the effects of the geology of a basin on streamflow (Walton, 1965). As is expected, the flow duration curve of sub-basin W-1 is nearly horizontal, indicating a significant ground water component in its streamflow. The flow duration curves of sub-basins W-3 and S-4 are nearly vertical, which indicates a small ground water component in their streamflows. The flow duration curves of all the other sub-basins plot in intermediate positions between the curve of W-1 and the curves of W-3 and S-4.

Walton (1965) suggested using the ratio $(Q25/Q75)^{1/2}$ to describe the slope of the flow duration curve as a quantitative index of the role of ground water (geology) in streamflow, where Q25 is the streamflow equalled or exceeded 25 percent of the time and Q75 is the streamflow equalled or exceeded 75 percent of the time. The following ratios were obtained:

Sub-basin	Ratio $(Q25/Q75)^{1/2}$
W-1	1.07
W-2	1.12
S-3	1.17
S-1	1.21
B-4	1.25
S-2	1.30
B-2	1.36
S-4	1.97
W-3	2.06

Sub-basins with small ratios have a substantial ground water component whereas sub-basins with large ratios have a small ground water component.

GROUND WATER

General Principles and Definitions

Subsurface waters occur in two zones below the land surface: the unsaturated zone and the saturated zone. The first zone extends from the land surface down to the water table and includes the capillary fringe. This zone contains liquid water under less than atmospheric pressure, and water vapour and air, or other gases, at atmospheric pressure. In parts of this zone, interstices, particularly the small ones , may be temporarily or permanently filled with water. The second zone (i.e. the saturated zone) is that zone in which all voids, large and small, are filled with water under pressure greater than atmospheric (Lohman et al, 1972). The top boundary of the saturated zone, at which pressure is atmospheric, is called the water table.

Ground water is that part of the subsurface waters which occurs in the zone of saturation and is subject to continuous movement. The geometry and intensity of ground water flow are dependent on the hydrogeologic environment consisting of topography, climate and geology (To'th, 1972). The source of and recharge to ground water comes from precipitation, directly by infiltration from the land surface or indirectly by surface water leaking from streams, ditches or ponds. The land surface topography exerts a controlling influence upon the configuration of the water table, the distribution of flow systems, and consequently ground water movement. The occurence, movement, quality and availability of ground water also depends on geologic factors, in particular, lithology, porosity, permeability and the areal distribution of various deposits.

Ground water occurs in the openings within the aquifer. These openings may be in the form of pore spaces between grains of silt, sand or gravel, or in the form of solution cavities, fissures, joints, and bedding planes. The ratio of the volume of the pore spaces to the total volume of the water bearing material is called the porosity.

In unconsolidated deposits, porosity is controlled by the shape, arrangement, degree of sorting and cementation of the particles. Porosity is high in well sorted deposits and low in poorly sorted and highly cemented deposits. In consolidated rocks, porosity is dependent on the extent of cementation and the degree of development of the fissure system and solution cavity openings. Effective porosity refers to the amount of interconnected pore spaces or other openings available for fluid transmission.

Porosity is not a measure of the amount of water that an aquifer will ultimately yield. The ratio of the volume of water which the rock, after being saturated, will yield by gravity drainage, to the volume of the rock, is called the specific yield, s_y. The specific retention, Sr, is the complement of the specific yield. It is the ratio of the volume of the water which the rock, after being saturated, will retain against the force of gravity, to the volume of the rock.

The storage coefficient, S, is the volume of water an aquifer releases from or takes in storage, per unit surface area of the aquifer, per unit change in head. In an unconfined aquifer, the storage coefficient is virtually equal to the specific yield. However, in a confined aquifer, it is less than the specific yield as the water derived from storage comes from expansion of the water and compression of the aquifer. Similarly, water added to storage is accommodated by compression of the water and expansion of the aquifer (Lohman et al, 1972).

Ground water flow occurs under a hydraulic gradient which is defined as the change in static head per unit of distance along the ground water flow path. The relative ease with which a water bearing material can transmit water under a hydraulic gradient is a measure of the permeability of the material. The hydraulic conductivity, K, replaces the term "coefficient of permeability" (Lohman et al, 1972), and is a measure of the capacity of a material to transmit water. If a porous medium is isotropic and the fluid is homogeneous, the hydraulic conductivity of the medium is the volume

of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient, through a unit area measured at right angles to the direction of flow. For three dimensional ground water flow in an anisotropic porous medium, the resultant hydraulic gradient is no longer parallel to the flow lines, as is the case for an isotropic porous medium. Therefore, the permeability is expressed by the hydraulic conductivity coefficients: K_{xy}, K_{xy}, K_{xz}, K_{yy}, K_{yx}, K_{yz}, K_{zz}, K_{zx}, and K_{zy}, which are the components of a second order tensor which is generally symmetric. Most aquifers in nature are anisotropic and nonhomogeneous; however, in applied hydrology, it is often not possible to determine the hydraulic conductivities in all directions and the aquifers are often assumed to be isotropic and homogeneous.

Transmissivity, T, is the rate at which water at the prevailing kinematic viscosity is transmitted through a unit width of the aquifer, under a unit hydraulic gradient, and is equal to the product of the hydraulic conductivity of the aquifer and its thickness. Transmissivity replaces the term "coefficient of transmissibility" because by convention, it is considered a property of the aquifer, which is transmissive (Lohman et al, 1972).

In applied hydrogeology, pumping and recovery tests of wells generally give the most reliable results for determination of the hydrogeologic constants. Often, however, the only available data for a particular well is the final drawdown associated with a pumping rate for a period of time. These data can be combined in the specific capacity index to describe the water-yielding characteristics of the formation the well taps.

The specific capacity of a well is defined as its yield per unit of drawdown, expressed as liters per second per meter of drawdown (L/s/m). Dividing the yield of a well by the drawdown for a specific time during a pump test, gives the value of specific capacity.

The specific capacity of a well is a function of the type of the aquifer, well diameter, pumping time, partial penetration, hydrogeologic boundaries, and well construction characteristics. Because of the above-mentioned constraints, the specific capacity is not an exact criterion with which to estimate the transmissivity; however, it is a useful index to describe the water yielding characteristics of a well and of the formation the well taps. In general, high specific capacities are indicative of high transmissivities and, consequently, high water yielding capacities.

Ground Water Occurrence in the Bedrock

Within the study area, ground water occurs in fissures, joints and bedding planes of the bedrock formations. The development of the fracture system within the bedrock is relatively limited because the region was tectonically relatively stable throughout geologic time. The widening of the fractures existing within the bedrock, and consequently the formation of solution cavities due to dissolution of the calcium carbonate in the limestone by chemically aggressive ground water, appears to be of minor importance in the study area. The absence of such solution cavities within the bedrock formation can be explained as follows:

(i) The limestone is dense, compact and impure and with a high clay content, tending to hinder its dissolution.

(ii) The number of primary and secondary fissures and joints is relatively limited and their distribution is irregular, both horizontally and vertically; therefore, only a limited area of the rock is open to dissolution.

(iii) As a result of (ii), the permeability of the bedrock is very small; therefore, the quantity of chemically aggressive water acting on it is limited.

(iv) The presence of a glacial mantle with a relatively high carbonate content results in percolating ground water becoming almost saturated with respect to HCO_3^- and Ca^{++} ions before it reaches the bedrock where the weathered surface had been scoured to varying degrees by glacial action.

Over 70 wells in the study area are completed in the bedrock. Most of these wells are located within the Iroquois Plain physiographic unit where the thickness of the overburden is small, and they penetrate only the upper few meters of the bedrock. Four wells are reported to penetrate the bedrock from 21 to 24 m, one well to 72 m and another to 91 m. These deep wells are either dry or have a very low yield. It would appear that ground water supplies obtained from the bedrock come mainly from its upper part, where the availability of ground water is controlled by the distribution of the water yielding openings and the type and thickness of the overburden deposits.

In general, wells completed in the bedrock are suitable for supplying domestic requirements only. The production from these wells ranges from a few liters per day to a few liters per minute, with some of the wells being pumped dry under normal usage.

As was mentioned earlier, the specific capacity data give more information about the water yielding characteristics of wells and of the formations these wells penetrate, than the pumping rates of the wells alone.

Specific capacity data of wells completed in the bedrock which have common radii and pumping periods, were tabulated in order of magnitude and frequencies were computed using the formula:

$$P = \frac{m}{n + 1} \qquad (7)$$

where:

	P	=	probability
	m	=	order number or items arranged in ascending magnitude; thus m = 1 for the smallest item,
	n	=	total number of items

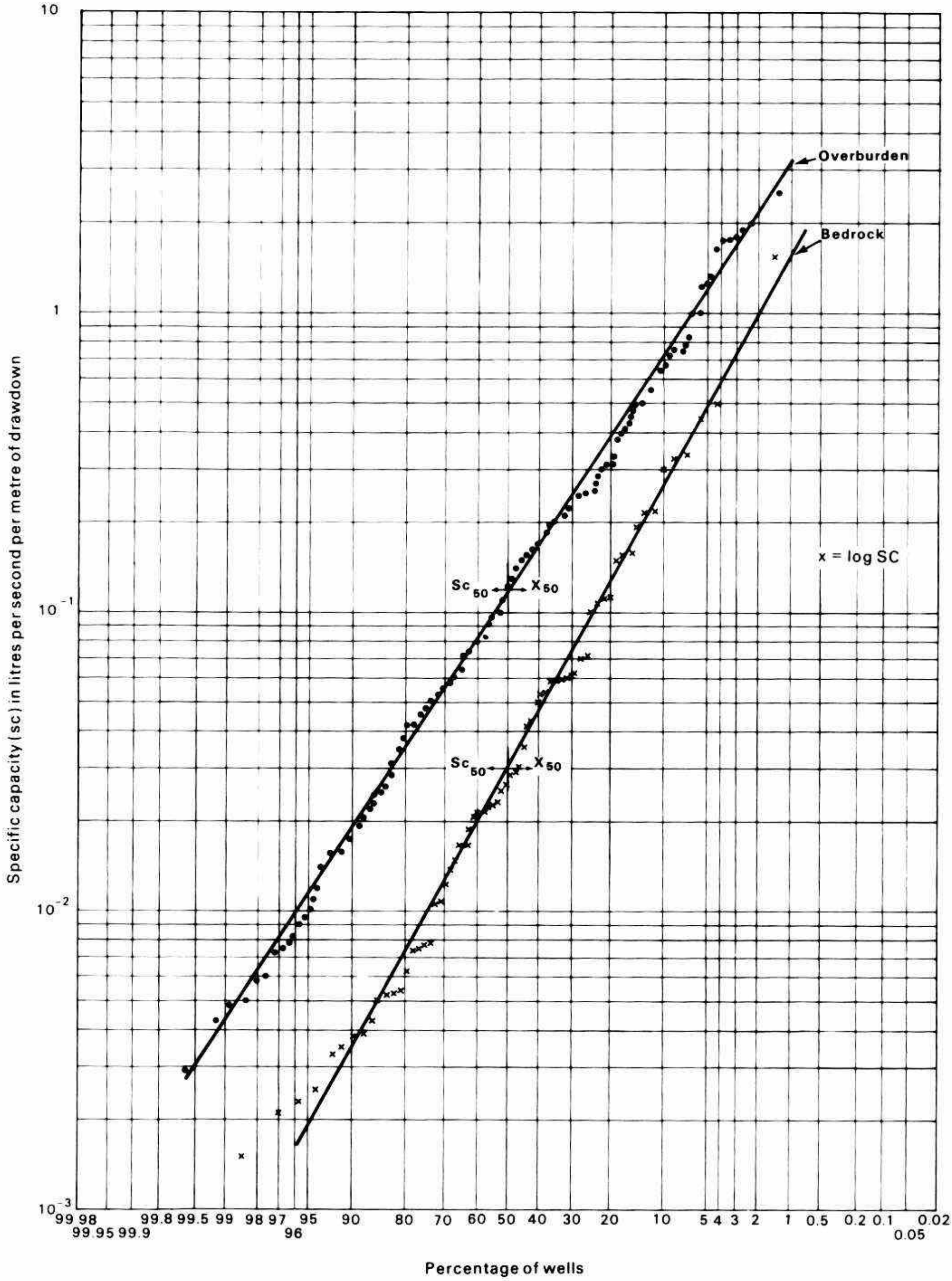


Figure 17. Relationship between specific capacities of wells completed in the overburden and in the bedrock.

Values of specific capacity (SC_i, i = 1, n) were then plotted against percent of wells, on logarithmic probability paper (Figure 17). The specific capacity values for wells completed in the bedrock plot as approximately a straight line on the logarithmic probability paper, indicating that the sample has a lognormal frequency distribution. Therefore, it could be concluded that the most probable specific capacity value for a well completed in the bedrock is equal to the geometric mean of the individual specific capacities. For a sample of size n, the geometric mean (G) is defined as:

$$G = \sqrt[n]{(SC_1)\ (SC_2)\ldots\ldots\ldots\ldots\ldots(SC_n)} \qquad (8)$$

In the light of the lognormal frequency distribution, it is worth defining the set x, where $x_i = \log SC_i$. It can be shown that the log of the geometric mean (log G) of the SC - distribution is equal to the arithmetic mean (X) of the x-distribution (Freeze, 1972). On the log-probability plot (Figure 17), $X = X_{50}$, and $G = SC_{50}$, where X_{50} and SC_{50} are the values of X and SC at the 50 percent probability level.

The geometric mean of the specific capacity values of wells completed in the bedrock is equal to 0.03 l/s/m. This indicates that the bedrock in the study area has a low water yielding capacity and is of limited importance as an aquifer. Because the bedrock represents the base on which the overburden rests within the study area, it is possible to conclude that the bulk of ground water recharge, transmission and discharge, occurs within the overburden, with its generally higher specific capacity characteristics as shown on Figure 17. Consequently, the regional ground water flow, within the bedrock, is of minor importance and takes place mainly within its top few meters.

Ground Water Occurrence in the Overburden

The overburden in the study area is composed of glacial, glacio-fluvial and glacio-lacustrine deposits, as well as recent alluvium and organic matter. Overburden materials vary in composition and grain size from clay to boulders and ground water occurs within the overburden in the pore spaces between the grains of the unconsolidated materials. Clays, though highly porous, have such small pore spaces that a large percentage of the water contained in them is bound to the particles by forces of molecular adhesion. Clay-rich sediments are usually described as being impermeable. The coarse grained sand and gravel deposits, on the other hand, have large pore spaces which allow ground water to move more freely. These deposits constitute the aquifers within the overburden in the study area. In general, these aquifers are highly permeable and they yield water more readily to wells and springs. Their importance, however, as sources for water supply purposes, is a function of their areal distribution, thickness and geologic setting. The geologic setting of an aquifer determines its opportunity for being recharged which is at a maximum when the aquifer is exposed at surface and at a minimum when the aquifer is deeply buried and completely confined by impermeable deposits. The overburden within the study area, is highly variable, both vertically and laterally. Examination of the surficial geology along the shoreline of Lake Ontario, where the overburden section is well exposed, clearly illustrates this point. Therefore, while it is possible to define the areal distribution and to a lesser degree, the thickness of the sand and gravel deposits that are displayed at surface within the study area, the same is not always true when these deposits are buried at some depth within the overburden. Two approaches are available to unlock this perplexity. The first approach is to utilize data on water wells on file with the MOE and the second is to rely on the suggested stratigraphy scheme for the overburden deposits in the study area. Both these approaches will be used in conjunction with data on surficial geology to describe the occurrence of ground water and water yielding characteristics of various deposits within the overburden in the study area.

In general, the ground water availabiltiy in the overburden ranges from poor to good. Most wells are used for domestic supplies and livestock requirements. Locally, overburden aquifers are the most productive sources of ground water within the study area. The Tyrone springs are used as a water supply source for the Town of Bowmanville. These springs satisfy approximately half of the water requirements of the town, with the other half being obtained from Lake Ontario. The water supply for the Village of Newcastle is obtained from a gravel aquifer which appears to be a buried channel located in the vicinity of the village. Two municipal wells tap this aquifer and produce over 15 l/s. The Police Village of Orono obtains its water supply from a municipal well drilled in an overburden aquifer.

Over 200 wells are completed in the overburden. Specific capacity data on 97 wells, which have common radii and pumping periods, were tabulated in order of magnitude, and frequencies were computed using Equation 7. Values of specific capacity were then plotted against percent of wells, on logarithmic probability paper (Figure 17). The specific capacity values for the sample approximate a straight line, indicating that an assumption of a lognormal frequency distribution is acceptable. The most probable specific capacity value for a well completed in the overburden, therefore, is equal to the geometric mean of the individual specific capacities. The geometric mean of the specific capacity values for wells completed in the overburden is equal to 0.12 l/s/m, compared to 0.03 l/s/m for wells completed in the bedrock. This indicates that the water yielding characteristics of the overburden deposits is higher than that of the bedrock and that the bulk of ground water recharge, transmission and discharge occurs within the overburden. In general, high specific capacity values (up to 2.5 l/s/m) are observed in wells which tap extensive aquifers that are exposed at or are easily rechargeable from surface. Intermediate specific capacity values are observed in wells drilled within the ground moraine which intercept a lense of sand or gravel at depth. Low specific capacity values (up to 0.003 L/s/m) are observed in wells which penetrate clay till or clay silt sediments.

The following is a description of the water yielding characteristics of various types of deposits within the overburden in the study area.

Buried Channels - Data on bedrock wells in the study area show the presence of bedrock valleys which are indicative of preglacial drainage. Singer (1974) published a map showing the topography of bedrock and the pattern of bedrock valleys for a strip along the north shore of Lake Ontario which includes the Iroquois Plain physiographic unit in the study area. Logs of wells which penetrate these bedrock valleys indicated the presence of gravel-like deposits up to 6 m in thickness. Figure 18 shows the approximate areal distribution of these channel deposits. The figure indicates that these deposits are present to the east of the Town of Bowmanville, in the vicinity of the Village of Newcastle and to its north. The water yielding characteristics of these channel deposits range from adequate to excellent depending on their thickness and they provide enough water supply for domestic and farm needs. In addition, the water supply for the Village of Newcastle is believed to originate from these channel deposits. Two municipal wells tap the aquifer and produce over 15 l/s/m.

Glacial Deposits - Four tills of glacial origin were identified in the study area: a Basal Till, a Lower Till, a Middle Till and an Upper Till. All these tills are heterogeneous, unsorted mixtures of particles ranging in size from fine clay to boulders. Both the Lower and Middle tills are dense and contain an exceptionally high percentage of silt and clay which makes them practically impermeable. This hydrogeologic characteristic of both tills hinders the leakage of water to underlying formations and induces the ground water to flow laterally along their top surface. Available data from water wells do not allow the determination of the exact areal distribution of these two tills. However, evidence of the presence of a dense clay till in the Oak Ridges is available. This fact suggests that ground water recharge to the bedrock within the Oak Ridges is not significant. In addition, the Basal Till was identified in the Oak Ridges section which will further impede the recharge to the bedrock in that area.

Ground moraine, which is composed of sandy till, constitutes the Upper Glacial Unit and is the predominant surface deposit in the study area (Figure 18). This till, although sandy in texture, contains a high percentage of silt and clay. The result is that low permeability is an inherent characteristic of this till. Nevertheless, this Upper Till is not completely impermeable and it permits the vertical leakage of water to recharge the sand and gravel deposits which may be present at depth. Wells attempted in this till are characterized by a poor yield if coarse-grained sediments are not encountered.

Silts and Clays of Glacio-Lacustrine Origin - Silts and clays of glacio-lacustrine origin are associated with the Clarke Deposits Unit, as well as with the deposits of Lake Iroquois. As was mentioned earlier, the Clarke Deposits Unit is made up of a Lower part consisting of varved clay or thin bedded clay silt and an upper part made up of sand. The Clarke Deposits Unit was identified in the examined overburden section along the Lake Ontario shoreline. A similar unit was also identified in the Oak Ridges section. Visual observations of springs and seepage faces on the Lake Ontario bluffs indicate that ground water discharges at the base of the Clarke sands. This hydrogeological property facilitated the mapping of the contact between the sands and the less permeable varved clay or clay-silt beds. Available data do not permit the mapping of the exact areal distribution of the Clarke Deposits. However, when these deposits are present in a section, their upper sandy part will act as an aquifer and their lower lacustrine part will act as an aquiclude.

Varved clays and silts are also associated with the Lake Iroquois deposits. These lacustrine sediments are displayed at surface in the lower end of the study area. The thickness of these sediments ranges from 0 up to 8 m. Because of their low permeability, they hinder the recharge to underlying formations.

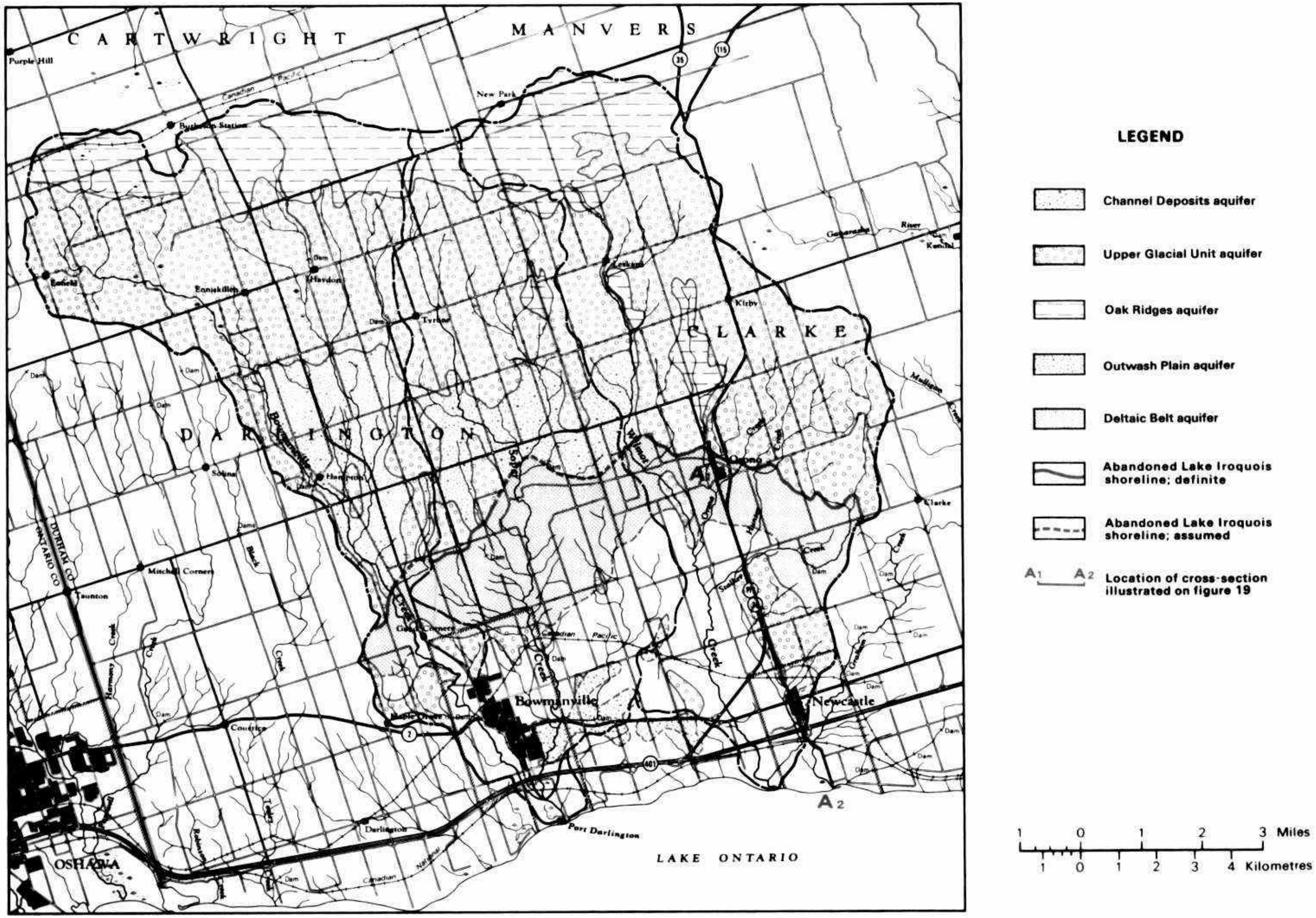


Figure 18. Major aquifers in the study area

From the foregoing, it is clear that the overburden section in the study area contains a number of units which are characterized by very low permeability. Four of these units, namely, the Basal Till, the Lower Till, the lower member of the Clarke Deposits Unit and the Middle Till are found within base of the overburden section overlying the bedrock. As a result of this geological setting, it is possible to arrive at the following conclusions:

(i) The net recharge to the bedrock in the study area is small and therefore, the importance of the ground water flow regime in the bedrock is minor.

(ii) The role of the coarse grained deposits contained within the above-mentioned four units as aquifers is not significant.

(iii) The principal ground water flow occurs within the upper part of the overburden and could be conveniently assumed to be two-dimensional.

<u>Gravels and Sands of Glacio-Fluvial and Proglacial Lake Origin</u> - These sediments are characterized by high permeability and water yielding characteristics which place them as the most important aquifers in the study area. Coarse grained deposits within the overburden are associated with the Lower Glacio-Fluvial Unit, the Clarke Deposits Unit, the Upper Glacial Unit, the Oak Ridges interlobate moraine, and the early pro-glacial lakes and Lake Iroquois deposits.

The Lower Glacio-Fluvial Unit was identified in the Oak Ridges section. It consists of silt and fine sand up to 5 m in thickness. The unit is deeply buried and little is known about its areal extent. Available evidence indicates that the unit is overlain in the Oak Ridges by thick sequences of clay till and clay deposits which lessen significantly its opportunity of being recharged and reduce its importance as an aquifer.

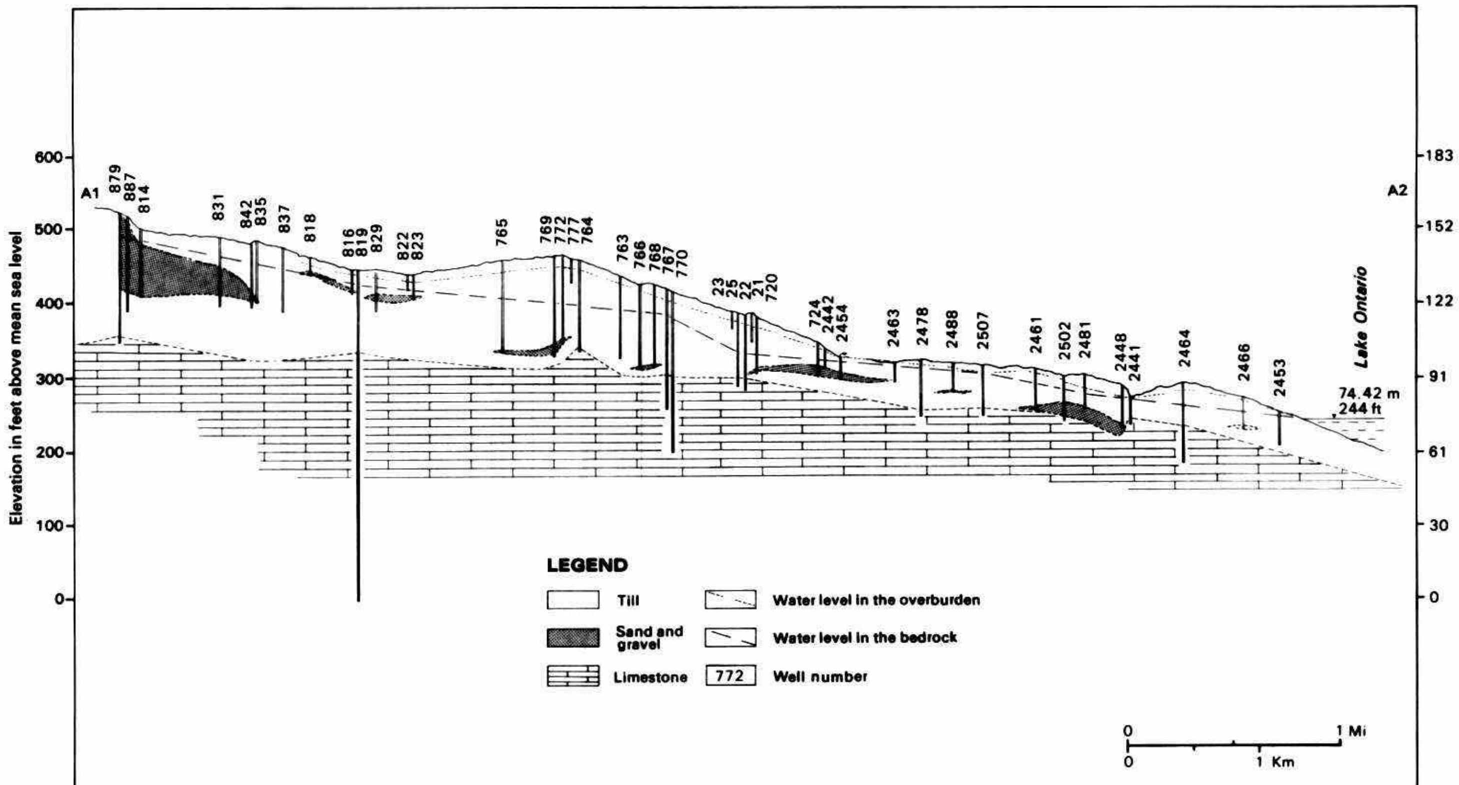


Figure 19. Cross-section A1-A2 extending from the Police Village of Orono to Bondhead on Lake Ontario. The location of this cross-section is shown on Figure 18; (from Singer, 1974).

The upper part of the Clarke deposits Unit is made up of sands. The Clarke sands constitute the main water bearing zone in the examined shoreline of Lake Ontario and ground water discharges at their base in the form of springs and seepage faces, (Singer, 1974). These sands, however, are missing in that part of the shoreline that constitutes the southern edge of the study area. Available data from water well records do not allow the mapping of the exact areal distribution of the Clarke sands. Their presence however, is suspected in the Iroquois Plain where some water wells penetrate sand beds that have a continuous thickness of over 30 m. Sands with similar stratigraphic position were identified, also, in the Oak Ridges section where they are semi-confined by thick sandy till deposits. Due to the lack of data, it is not possible to identify the water yielding potential of this aquifer. One might suspect, however, that it could represent an important source of ground water within the Till Plain which is sparsely populated at present.

As was described previously, along the present-day shore of Lake Ontario discontinuous, stratified deposits of silt and very compact sands, separate the two till sheets of the Upper Glacial Unit. These deposits represent the second water bearing zone within the overburden in the examined shoreline. Wells attempted in the ground moraine within the study area often encounter silt and sand deposits which are likely associated with the Upper Glacial Unit. As in the case along the shoreline, these deposits are discontinuous and appear to be in most instances, thinly isolated bodies (Figure 19). Nevertheless, these deposits commonly yield adequate water supplies to meet domestic and livestock requirements.

Data collected from deep observation wells drilled in the Oak Ridges area (Figure 7) indicates that the ridges have a capping of sands and gravels with minor amounts of silts and till, resting on top of sandy till which appears to represent the lower till sheet of the Upper Glacial Unit. These sand and gravel deposits are displayed at surface throughout most of the Oak Ridges and represent the most important overburden aquifer within the study area.

The aquifer has a surface area of approximately 27 km^2 which represents about 11 percent of the total drainage area. The thickness of the aquifer ranges from a few meters up to 100 m. The aquifer forms an elevated plateau rising above the level of the Till Plain along its southern boundary (Figure 18). Its surface is covered with a sand loam to sandy topsoil and its relief is knob-and-kettle with virtual lack of surface drainage. Rain and snowmelt infiltrate readily through the soil and either return back to the atmosphere via evapotranspiration or percolate down to recharge the ground water body whenever the soil moisture is above field capacity. This leaves little or no water for overland flow. Because the aquifer is underlain by till deposits which have lower permeability, the bulk of ground water moves laterally within the aquifer in a southward direction and issues at its base along the southern shoulder of the ridges as springs and seepage faces, to become a part of the surface runoff cycle. A smaller part of the ground water leaks through the till deposits at the base of the aquifer and reaches eventually the bedrock to become a part of the regional ground water flow system. Hence, the aquifer itself acts as a major recharge zone, whereas it southern edge constitutes a major discharge zone.

Few wells were drilled in the Oak Ridges within the study area; this makes an evaluation of the water yielding characteristics of the aquifer from water wells data a difficult task. A baseflow analysis of the streamflow at station W-1 which drains 10.8 km^2 of the aquifer, gives an average ground water discharge of 10 $L/s/km^2$. This is almost double the average ground water discharge per unit area for the whole drainage basin.

An outwash plain which extends between the villages of Hampton on the west, Enniskillen and Tyrone to the north, Orono to the east and is bounded by the Lake Iroquois shoreline to the south, represents the second most important aquifer in the study area. The outwash aquifer consists of sands and gravels which range in thickness from 2 to 24 m and cover an area of approximately 20 km^2. The aquifer

is underlain by sandy till of the Upper Glacial Unit and its surface is intersected by the Bowmanville, Soper and Wilmot Creeks and their tributaries. Excess water from rain and snowmelt percolates to the aquifer and moves mainly laterally to the nearest streams to discharge as baseflow.

Over 37 wells ranging in depth from 7 to 60 m are located within this outwash aquifer. Nine of these wells were drilled in stream valleys and are flowing, which indicates that the ground water flow is towards these valleys. The yield of the wells varies from 0.2 to 3.1 l/s and the geometric mean of the specific capacity values for these wells equals 0.19 l/s/m.

As was described earlier, sand and gravel bars and beach terraces are well displayed at surface along the abandoned Lake Iroquois shoreline (Figure 18). The thickness of these deposits varies from 1 to 8 m. Immediately to the south of the Iroquois shoreline deposits, there is a flat, deltaic belt up to 3 km in width, composed for the most part of fine-grained gravel and sand. Logs of wells drilled within this deltaic belt and particularly those located to the southwest of Gaud Corners on Bowmanville Creek, approximately 1.6 km south of Stephens Gulch on Soper Creek and immediately to the south of Orono on Wilmot Creek, indicate the presence of sand beds that have a continuous thickness of over 30 m. The origin of these sands is unclear. They may be deltaic deposits formed at the mouths of the Bowmanville, Soper and Wilmot Creeks as they entered Lake Iroquois or a lower level postglacial lake. On the other hand, the uppermost few meters of those deposits could be associated with Lake Iroquois, while their lower part could be associated with fluvial deposits of the Upper Glacial Unit or with the Clarke sands. In any event, the Iroquois shoreline deposits and the deltaic belt represent the third most important surficial aquifer in the study area.

Over 35 wells are located within the Lake Iroquois aquifer and 12 of these wells penetrate the bedrock. The yield of these wells ranges from 0.07 to 6.4 l/s. The geometric mean of the specific capacity values for those wells that do not reach the bedrock is 0.16 l/s/m.

Ground Water Movement

Ground water is subject to continuous movement, the rate of which is a function of the hydrogeologic characteristics of the material in which it moves, and the existing hydraulic gradients and temperatures. The existence of a three dimensional, continuous ground water domain in a corresponding three dimensional potential field has been established and developed by Hubbert (1940), To'th (1962, 1963), and Freeze and Witherspoon (1966, 1967).

The ground water hydraulic potential at a given point in this domain where the flow is at low velocity (Darcian) is given by:

$$Hp = gz + \frac{P - Po}{d} \tag{7}$$

where:
- Hp = hydraulic potential at a given point in the field,
- g = gravity acceleration,
- z = elevation at the point above an assumed datum,
- Po = atmospheric pressure,
- P = pressure at given point,
- d = density of water. (Hubbert, 1940)

The hydraulic head (h) equals the hydraulic potential (H_p) divided by the gravity acceleration (g) and is measured in meters above a datum (usually m.s.l.). Because the hydraulic head is obtained by dividing the hydraulic potential by a constant, it is a potential quantity itself and obeys the laws of potential theory (Freeze and Witherspoon, 1966). The hydraulic head therefore, can be used as a potential function to describe the ground water flow system.

Within the framework of this approach to the ground water regime, the water table is defined as the upper boundary of the ground water flow system at which the absolute pressure is atmospheric. The ground water domain contains areas of recharge, lateral transfer and discharge. Recharge areas are defined as those areas where water, from precipitation or surface bodies of water, enters the ground

water system at the water table surface and flows downward away from it within the saturated zone. Discharge areas are those where the flow of ground water is towards the water table within the saturated zone and water is removed from the ground water system, usually to surface water flow (Freeze, 1969).

In order to solve ground water flow problems, only two equations are available: the equation of motion (Darcy's Law) and the equation of continuity. A combination of these two equations provides the equation that governs the ground water flow. Under natural conditions the water table which represents the upper boundary of the ground water flow regime fluctuates with time, depending on the rates of recharge and discharge which are different in time and space. Therefore, the ground water flow in a basin is basically in an unsteady state. Strictly speaking, steady state ground water flow occurs only if the position of the water table is in a state of dynamic equilibrium in space and time, which arises when the rates of recharge to and discharge from the water table are exactly the same; a case which is rarely true. Freeze (1969) points out, however, that the assumption of a steady state ground water flow in a basin is a valid approximation, if the range of the water table fluctuations is only a small percentage of the total saturated depth and if the relative configuration of the water table remains the same throughout the cycle of fluctuations.

The general partial differential equation for steady flow of incompressible water in an anisotropic medium has the form:

$$\delta/\delta x \left[K(x,y,z)\ \frac{\delta h}{\delta x}\right] + \delta/\delta y \left[K(x,y,z)\ \frac{\delta h}{\delta y}\right] + \delta/\delta z \left[K(x,y,z)\ \frac{\delta h}{\delta z}\right] = 0 \qquad (8)$$

(Freeze and Witherspoon, 1966)

where: $K(x,y,z)$ = the hydraulic conductivities in the x,y,z directions,

h = the hydraulic head.

For a saturated homogeneous and isotropic medium, where K is constant, the steady flow of ground water is represented by Laplace's equation:

$$\frac{\delta^2 h}{\delta x^2} + \frac{\delta^2 h}{\delta y^2} + \frac{\delta^2 h}{\delta z^2} = 0 \qquad (9)$$

The approximate partial differential equaiton governing the unsteady flow of water in a confined and and isotropic aquifer of uniform thickness has the form:

$$\frac{\delta^2 h}{\delta x^2} + \frac{\delta^2 h}{\delta y^2} + \frac{\delta^2 h}{\delta z^2} = \frac{S}{KM} \frac{\delta h}{t} \qquad (11)$$

where: K = the hydraulic conductivity of the aquifer,
S = the storage coefficient,
m = the thickness of the aquifer,
t = time.

Equation 11 can be applied, also, to unconfined aquifers when the variations in the saturated thickness are relatively small.

The partial differential equation governing the unsteady two dimensional flow of water in confined and isotropic aquifer of uniform thickness is:

$$\frac{\delta^2 h}{\delta x^2} + \frac{\delta^2 h}{\delta y^2} = \frac{S}{T} \frac{\delta h}{\delta t} \qquad (12)$$

where: T = the transmissivity of the aquifer = Km.

Equation 12 forms the basis for ground water simulation within the Wilmot Creek basin. This equation has no general analytical solution, therefore it must be solved numerically using a finite element or finite difference approximation.

Water Table Configuration and Water Level Fluctuations

Knowledge of the water table configuration is of great importance in ground water investigations, as it indicates the direction and rate of ground water movement. Because ground water flow is, in essence, a three dimensional process, a lowering of the water level is usually observed in wells drilled in recharge zones and a rise of the water level is observed in wells drilled in discharge zones, as the depths of these wells drilled in discharge zones, as the depths of these wells increase. Therefore, the water level in a well does not coincide always with the water table level, rather it is a function of the well's location, depth, sub-surface geology and also, on occasion, ground water chemistry. This phenomenon is widely observed within the study area. Available data on water well records indicate that the water levels in wells located in the Oak Ridges area, which was identified as a major recharge zone, are indeed a function of depth. High water levels (5-10 m below ground surface) are observed in shallow wells and low water levels (30-40 m below ground surface) are observed in deep wells. The data also indicated that water levels in wells located near the ground water divide and completed in the bedrock, exhibit lower values in comparison with those wells completed in the overburden, the reverse picture being generally observed in bedrock wells located in the valleys. Further, the data indicate that most flowing wells are located in stream valleys.

From the foregoing, it is clear that the water table configuration should be based on data from shallow wells. Available data on shallow observation wells in the study area indicate that the water table configuration is a subdued reflection of the surface topography.

The highest water table elevation is observed in the Oak Ridges area and equals approximately 328 m and the lowest elevation is that of Lake Ontario and equals 74 m. This gives a mean ground water hydraulic gradient of approximately 0.015 (dimensionless), compared to a mean topographic gradient of approximately 0.017; this indicates that the water table follows the topography, at least on a

broad scale. The hydraulic gradient of the water table varies from one location to another, depending on the existing permeability configuration and the distribution of the geological formations. Low hydraulic gradients (0.001 - 0.009) are observed in the Oak Ridges area and within the Lake Iroquois Plain, whereas high hydraulic gradients (0.03 - 0.05) are observed mainly in the Till Plain.

Available data indicate that the ground water divides coincide very closely with the topographic divides. They also indicate that the ground water flows from these divides to the valleys with the general direction of flow being northwest-southeast from the Oak Ridges towards Lake Ontario. A general ground water level map for the study area is given by Funk (1977).

Data on ground water level fluctuations were collected from automatic water level recorders on 11 wells drilled for the IHD program. In addition, periodic water level measurements (once or twice a month) were made on 14 piezometers installed in 8 IHD wells, as well as from 22 abandoned shallow wells. The locations of these wells are given in Figure 3, which indicates most of these wells are located in the Wilmot Creek basin. Example hydrographs of water level fluctuations are given in Figures 20, 21, 22 and 23.

The most complete ground water level records are available for well No. W-5-B which is completed in the overburden (depth 46 m), where continuous measurements were made since September, 1966. Records for all the other wells contain gaps ranging in length from a few months to a number of years.

In order to fill in the missing data in the records of shallow observation wells where the ground water levels represent the closest approximation of the water table position, linear regression analyses were made observations at 16 shallow wells and observations at Well No. W-5-B. Table 27 gives the statistics of the water level measurements at these 16 shallow wells, whereas Table 28 gives the linear regression equations which express the statistical association between ground water level elevations in well No. W-5-B and corresponding elevations in the shallow wells. The coefficients of correlation for the derived regression equations range from 0.54

Figure 20 **Hydrograph of water level fluctuations in observation well B-4 A during the water year 1971-1972**; (from Singer, **1974**).

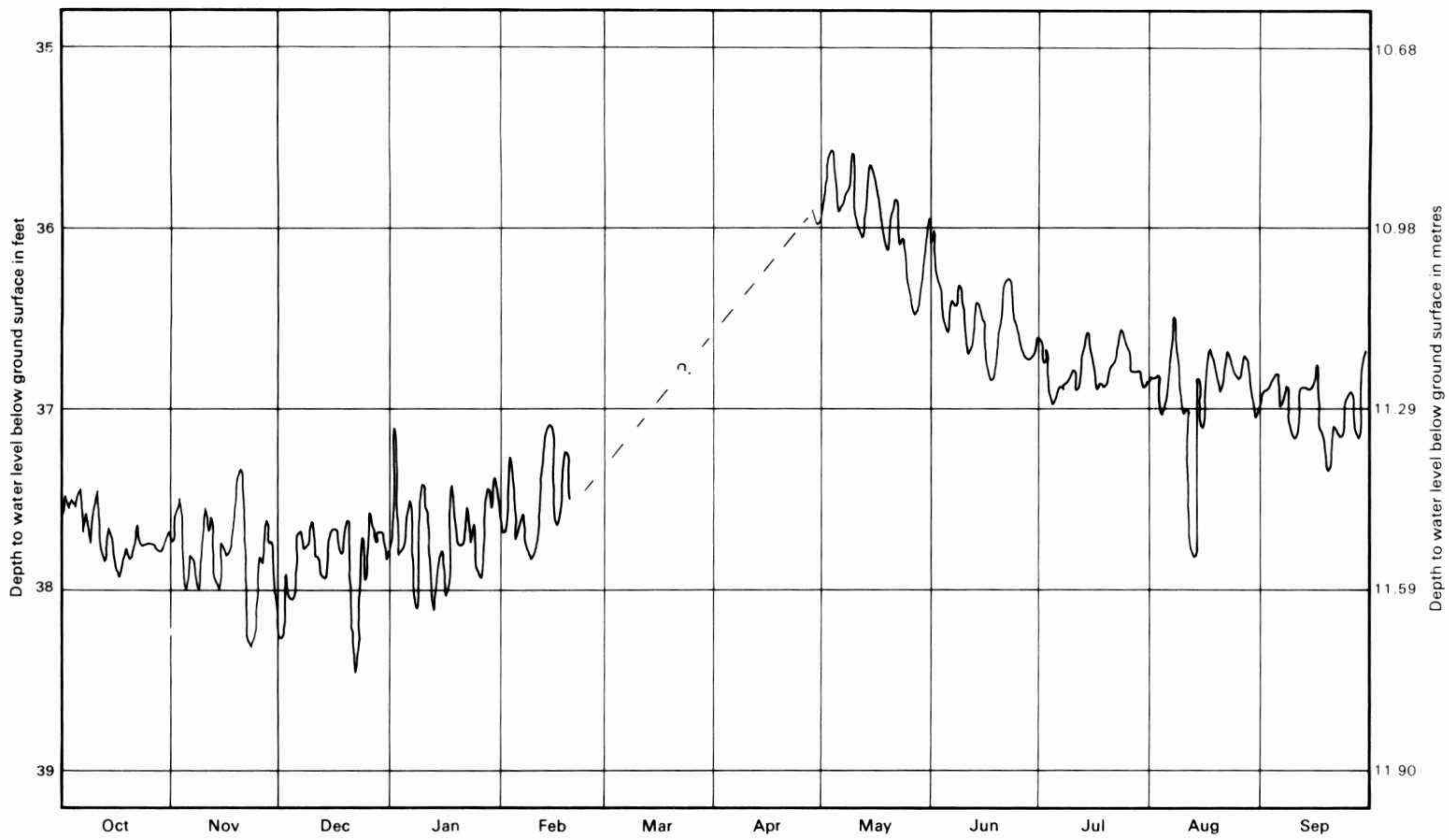


Figure 21. Hydrograph of water level fluctuations in observation well S-7 during the water year 1971-1972 ; (from Singer, 1974).

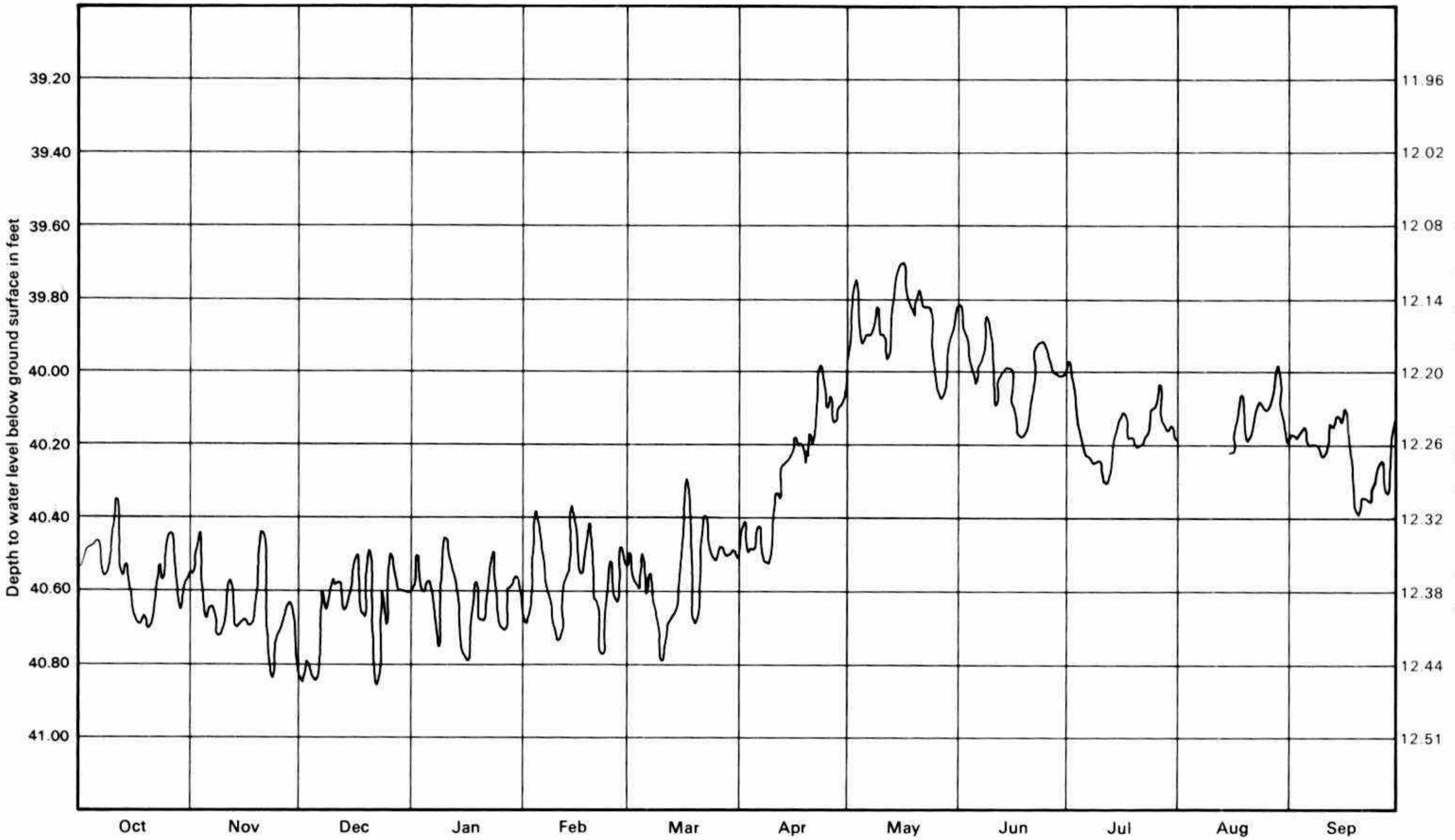


Figure 22. **Hydrograph of water level fluctuations in observation well W-3 during the water year 1971-1972 ; (from Singer, 1974).**

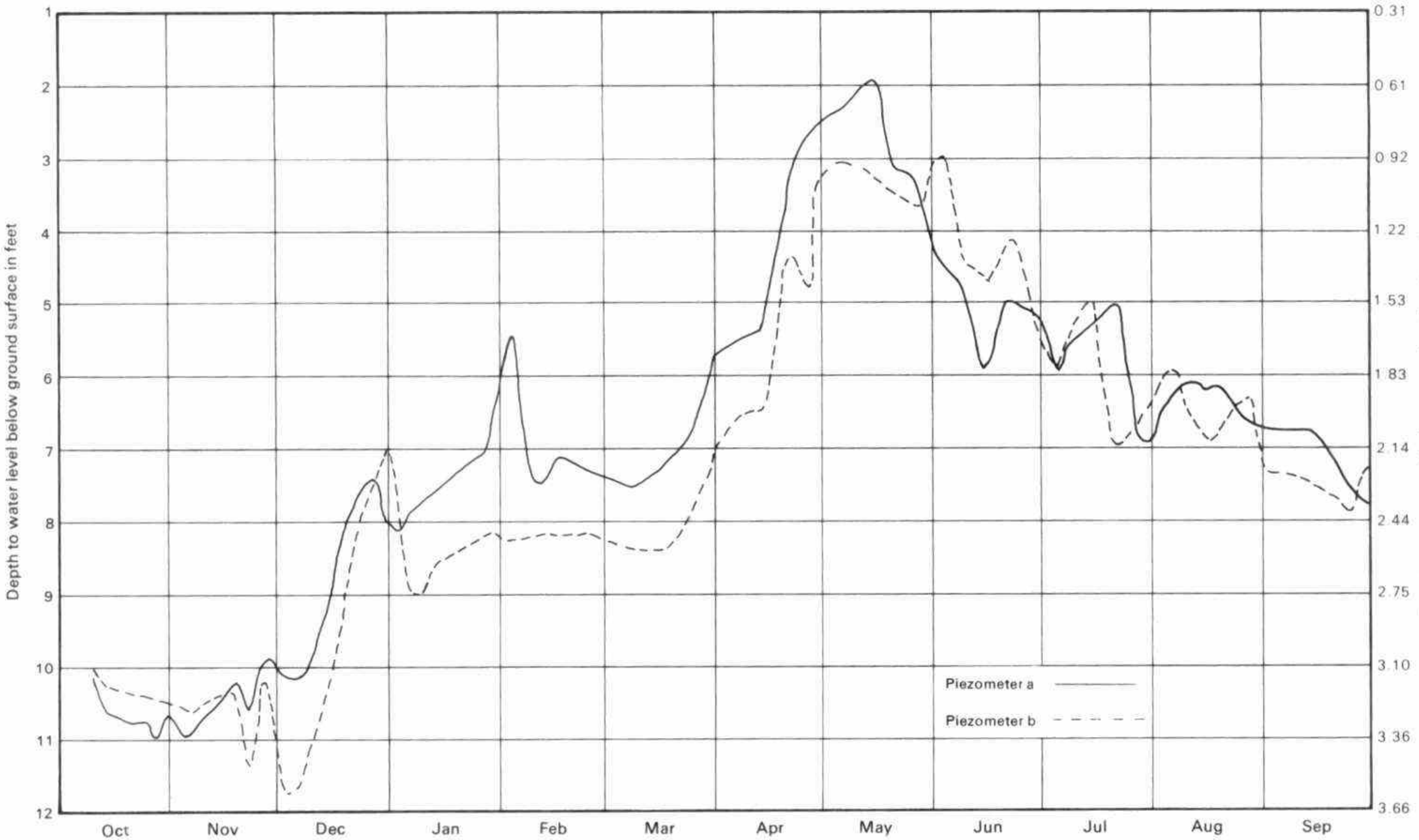


Figure 23. Hydrographs of water level fluctuations in observation well W-5A (piezometers a and b) during water year 1971-1972; (from Singer, 1974).

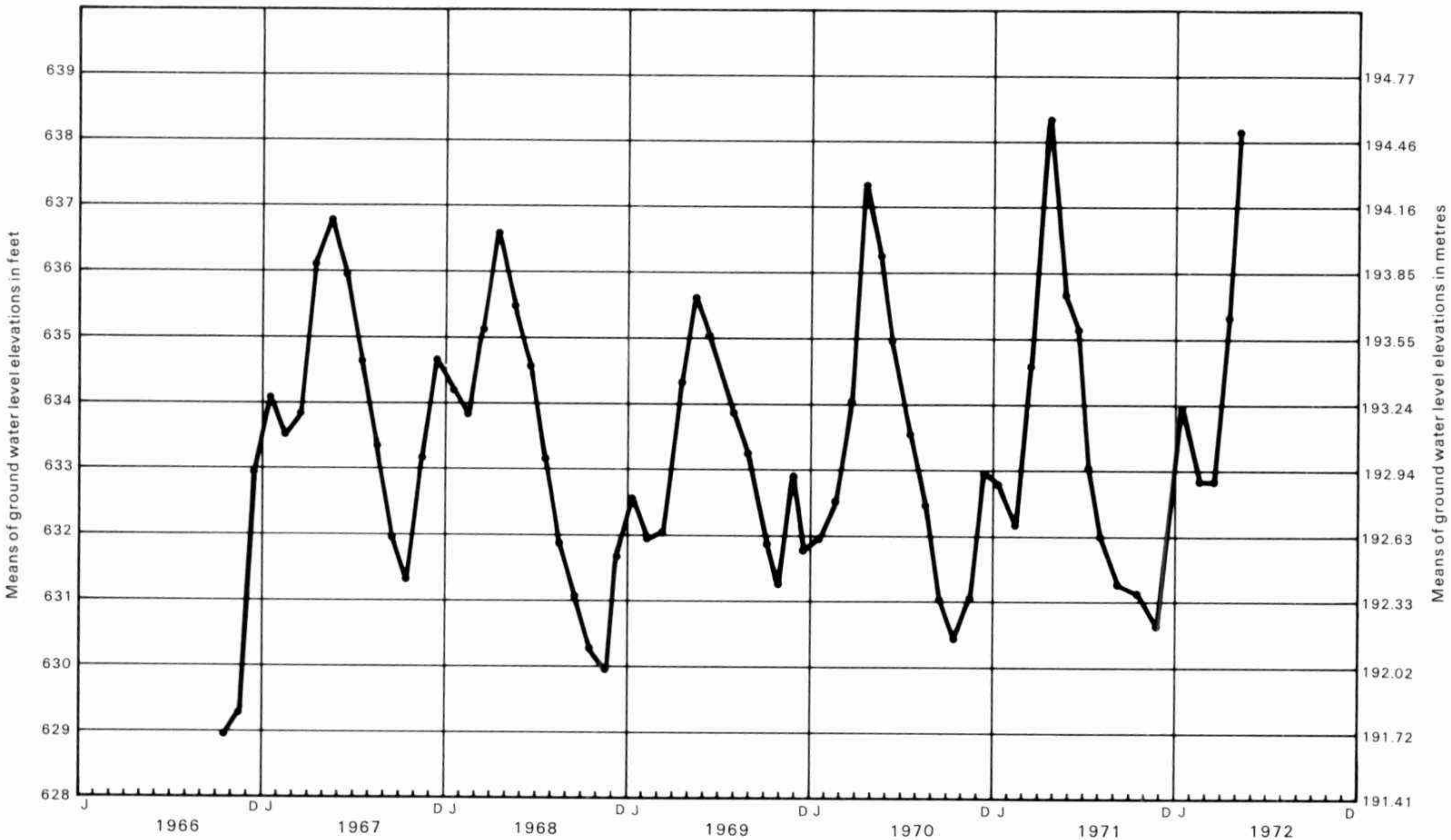


Figure 24. Hydrograph of monthly mean ground water level elevations in the Wilmot creek basin based on measurements from shallow observation wells.

to 0.94 and the standard errors of estimate range from 0.21 m to 1.28 m. The derived regression equations (Table 28) were used to fill in the missing data in the shallow well records. The completed sets of records at the 16 shallow wells and at well No. W-5-B were then used to arrive at the mean ground water level elevation on a monthly basis. Figure 24 shows the pattern of the monthly mean ground water level fluctuations which is typical for the Wilmot Creek basin. This pattern is believed to hold true throughout the study area. Based on Figure 24, it is possible to describe the ground water level variations on a seasonal basis in the study area as being a two peak-two recession process remarkably similar to that of the seasonal runoff variation process. The two peaks occur during the spring and fall with the first being high and the second moderate. The two recessions occur during the winter and summer with the first being short lived and the second steeper and longer lived.

Water levels in wells decline or rise mainly as a result of the net effect of the ground water recharge and discharge processes, thus reflecting the quantity of water stored within the ground water domain. A continual decline in water levels results when discharge exceeds recharge; water levels usually rise when recharge is greater than discharge. Therefore, the rising limbs of the peaks on the hydrograph of mean monthly ground water level fluctuations (Figure 24) represent periods of major recharge, whereas the falling limbs represent periods of major discharge. In the study area, the major recharge periods occur late in the fall or early winter when precipitation is in the form of rain, soil moisture is above field capacity and evapotranspiration is low and, also, during the spring when the snowpack melts, the soil moisture is above field capacity and evapotranspiration is still small. The major discharge periods occur during the winter when precipitation is mainly in the form of snow and, also, during the summer when the rain is used mainly to satisfy the soil moisture deficiency due to high evapotranspiration.

The Coefficients of Hydraulic Conductivity, Transmissivity and Storage

In dealing with quantitative ground water investigations in a basin, knowledge of the spatial variation of the hydraulic conductivity (transmissivity) and storage is required and no amount of mathematical ingenuity can make up for this lack. Pumping and recovery tests generally give the most reliable results for determination of these hydrogeologic constants. By means of such tests, the constants are determined insitu, and no disturbance of the profile takes place. An accurate determination of the spatial distribution of the hydrogeologic constants in the study area, where the geologic profile may change radically within short distances, would require an extremely large number of boreholes and pumping tests, which is simply not feasible. The only available alternative, therefore, is to utilize all the available data to arrive at values which represent approximately the values of the hydrogeologic constants of the real system.

Data from 104 pumping and recovery tests are available from wells located within and in the vicinity of the study area. The duration of pumping tests ranged from 1 to 12 hours. The data were used to arrive at an estimate of the transmissivity of different types of deposits (Singer, 1974). These estimates should be regarded as indicative of the magnitude rather than the absolute values of transmissivities for the following reasons:

(a) The data are related to the pumping wells themselves, no data are available for related observation wells.

(b) The duration of the pumping tests is short.

(c) The influence of partial penetration, screening methods and friction losses accompanying the upward flow of water, on the magnitude of drawdown, were not taken into account. These factors cause additional drawdown in the wells and lower the obtained transmissivity values.

The estimated transmissivity values were used to compute the hydraulic conductivities for till, sand, shale and limestone, by dividing the transmissivity by the thickness of the corresponding type of material.

The estimated hydraulic conductivity values for the till deposits in the study area ranged from 0.05 to 3.23 m/day, with an average value of 0.73 m/day. The hydraulic conductivity of the sand ranges from 0.54 to 18.45 m/day, with an average value of 3.96 m/day. The hydraulic conductivity of the limestone ranges from 0.005 to 1.86 m/day, with an average value of 0.39 m/day. Only one value is available for the hydraulic conductivity of the shale and this is 0.0009 m/day (Singer, 1974).

The mean values of the hydraulic conductivity of the till, sand, limestone and the one value for the shale, obtained from pumping and recovery tests, were used to estimate the total transmissivity of the overburden and the upper 15 m of the bedrock. Logs of wells completed in the bedrock were used for these estimations. Only the saturated thickness of the overburden was considered and the transmissivity at each well location was calculated by multiplying the saturated thickness of each type of deposit by its mean hydraulic conductivity and summing up the results. The estimated values of transmissivity for the overburden and the upper 15 m of the bedrock range from 1.1 to 313.1 m^2/day with an average of 26.8 m^2/day. The values given above should be regarded as indicative of the magnitude of the transmissivity values encountered within the study area. The transmissivity in one particular location could be completely different from that obtained from the mean hydraulic conductivity values assigned to various types of deposits. In addition, the transmissivity at one location is not constant, but is a function of the fluctuations of the ground water levels with time.

As was mentioned above, the available data on pumping and recovery tests are related to the pumping wells themselves and no data are available for related observation wells. Therefore, the storage coefficients cannot be determined from the data. Information on the magnitude of the storage coefficients, however, is essential for the evaluation of the natural ground water recharge and the modelling of the ground water flow system.

A geohydrologic method was used to determine the magnitude of the storage coefficients encountered in the study area. The method is based on the equation of continuity which is applied for a specific inventory period to selected sub-basins in the study area. The equation of continuity could be stated in the following form:

$$\text{Lateral inflow} - \text{Lateral outflow} - \text{Abstraction} + \text{Natural recharge} = \text{change of ground water storage} \tag{13}$$

Because most of the shallow observation wells are located within the Wilmot Creek basin, the method was applied to all the sub-basins within that watershed, namely, W-1, W-2, W-3 and local area (LA) which equals the difference between the total watershed area minus the areas of sub-basins W-2 and W-3.

Ground water abstraction from these sub-basins is extremely small and could be neglected. Further, the ground water divides for these sub-basins were assumed to coincide with topographic divides, which results in an assumption of zero lateral inflow. The lateral outflow from a sub-basin was assumed to consist of baseflow (natural ground water discharge) at the gauged outlet of the sub-basin. Based on the above-mentioned assumptions, the continuity equation reduces to:

$$Sg = Rg - Dg = dH \times S \tag{14}$$

where Sg is the change in ground water storage; Rg is the ground water recharge; Dg is the ground water discharge; dH is the change in mean ground water stage within a sub-basin during an inventory period and S is the mean storage coefficient.

Computations of the storage coefficients were made using Equation 14 and data for several inventory periods during the winter months when evapotranspiration and soil moisture changes are minimal. Further, the air temperature during the selected inventory periods was always below the freezing point so that precipitation in the form of snow would accumulate in the snowpack and no snowmelt would occur. These precautions assured that no overland flow or ground water recharge took place and that the streamflow was sustained basically by ground water discharge.

Approximately 10 inventory periods were selected for each sub-basin and the following mean storage coefficients for different sub-basins were computed:

Sub-Basin	Mean Storage Coefficient
W-1	0.060
W-2	0.037
W-3	0.003
Local Area (LA)	0.011

The values presented above represent estimates of the average storage coefficients for the respective sub-basins; however, the storage coefficient in one particular location in any sub-basin could be completely different from the computed value of the average storage coefficient.

Ground Water Discharge

Ground water discharge within the study area occurs mainly in the valleys of the Bowmanville, Soper and Wilmot creeks and their major tributaries. Ground water flows from the ground water divides towards these valleys and seeps into the streams as baseflow to become a part of the surface runoff process.

It is generally recognized that streamflow consists of the following three components:

(i) Direct runoff, which is that part of precipitation that flows over the land surface to the stream.
(ii) Interflow, which is that part of the precipitation which flows part of the way underground, but does not become part of the ground water body.
(iii) Baseflow, which is that part of the precipitation which reaches the streams as natural ground water discharge, after being a part of the ground water body.

To estimate the ground water discharge from a gauged area, one has to separate the streamflow into different components. Unfortunately, principles of separating the streamflow into components are not well developed and appear to be, in the case of complex streamflow hydrographs, somewhat arbitrary and artificial. It is believed, however, that if a certain method of streamflow separation is followed consistently, the same type of error will be commited systematically and therefore, useful results for comparison purposes can be obtained.

Baseflow Analyses - For the purpose of this study, natural ground water discharge from various basins and sub-basins in the study area was estimated by separating the streamflows at respective gauging stations into two components: a surface runoff component consisting of direct runoff and interflow, and a baseflow component.

The streamflow separation procedure which was employed consisted of the following steps (Figure 25):

(i) Hydrographs of daily streamflows for various gauging stations were plotted on semi-logarithmic paper.

(ii) Streamflow recession segments were assumed to be made up mainly of baseflow.

(iii) For an isolated or single storm event, the streamflow recession curve was extended along a straight line parallel to the time axis from point A (A is located at the base of the rising limb of the hydrograph, see Figure 25) to point B beneath the peak, and then along a straight line from point B to point C. C is the reflection point where the slope of the falling limb of the hydrograph changes (Figure 25, single storm). If point C is not well defined, its position is determined using an emperical equation defining N, the number of days after the peak at which direct runoff essentially ends. Linsley et al (1958) approximate N by the following equation:

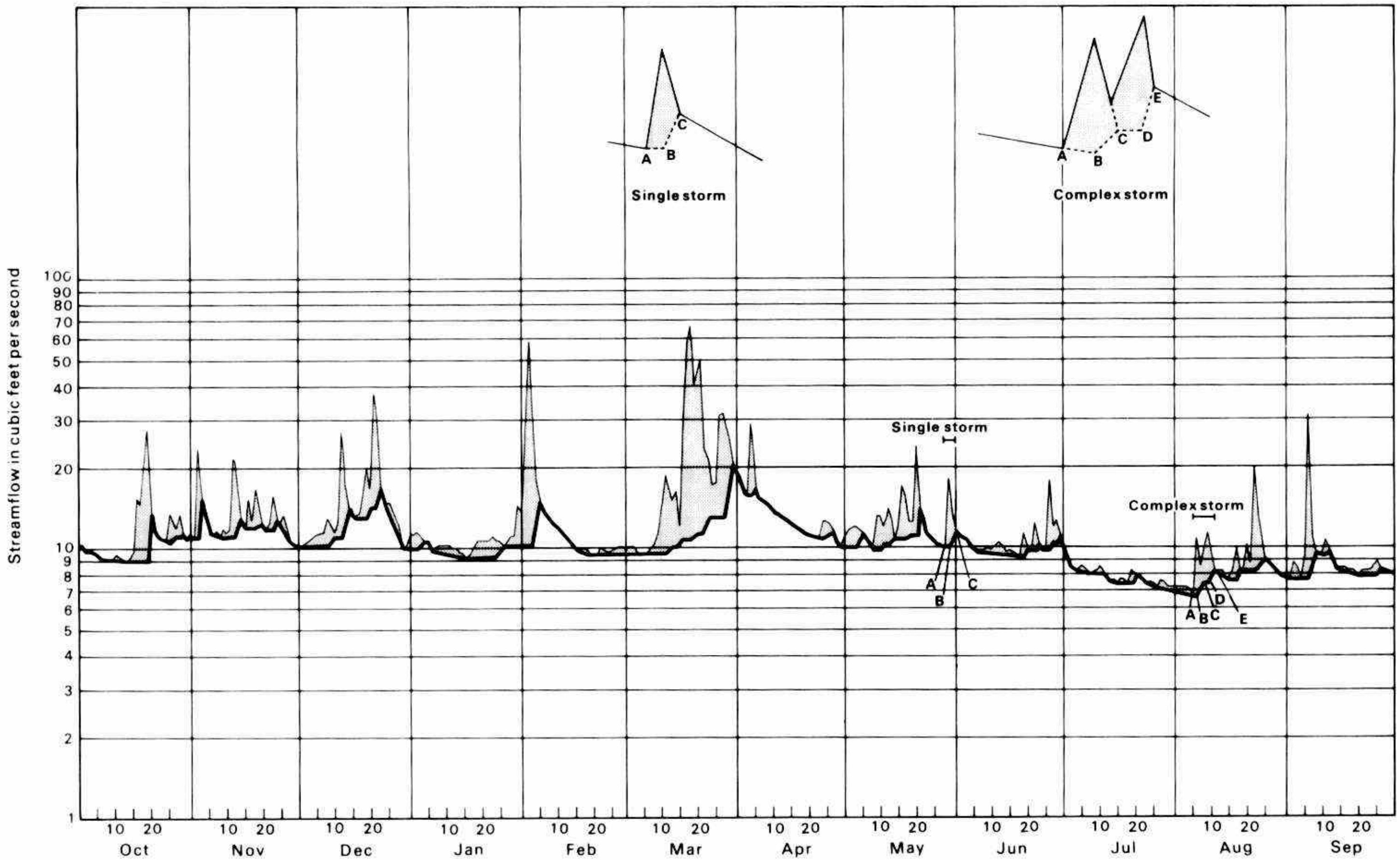


Figure 25. Separation of streamflow hydrograph into surface runoff component and baseflow at station (W-2) for the water year 1967 - 1968.

$$N = A^{0.2} \tag{15}$$

where: N = the number of days,
A = the drainage area in square miles.

(iv) For complex storms caused by two or more closely spaced rainfall events, the baseflow hydrograph is drawn as a broken line which extends from point A as in (iii), through all the points under the peaks, as well through all the real and imaginary reflection points. The location of an imaginary reflection point is determined by extending the falling limb to intersect a vertical line drawn N days after a peak. In the example on Figure 25, for a complex storm, the baseflow hydrograph is drawn along the line A-B-C-D-E, where A is located at the base of the first rising limb; B is located under the first peak; C is an imaginary reflection point which is N days after B; D is located under the second peak; and E is a real reflection point on the second falling limb.

The procedure outlined above was followed as consistently as possible to construct the baseflow hydrographs for various gauging stations in the study area. The constructed baseflow hydrographs were then used to estimate the daily, monthly and annual ground water discharge from the gauged basins and sub-basins. Table 29 gives estimates of the monthly and annual baseflows from these watersheds, their long term means and ratios of annual baseflows to annual runoffs and precipitations. The table indicates the following:

(i) Baseflow decreases slightly during the winter months (January - February); increases substantially during the spring months (March - May); decreases continuously during the summer and early fall months (June - October) and recovers during late fall and early winter months (November - December).

(ii) The above-described pattern is analogous to the patterns of the ground water level variation (process) and the surface runoff variation (process).

(iii) The ratios of annual baseflow to annual surface runoff vary from 92.0 percent at station W-1 to 27.1 percent at station W-3.

(iv) The ratios of annual baseflow to annual precipitation vary from 38.8 percent in sub-basin W-1 to 9.4 percent in sub-basin W-3.

(v) In terms of long term means of the ratios of annual baseflow to annual surface runoff the sub-basins, in the study area could be arranged in the following decreasing order: W-1, W-2, S-1, S-3, B-4, S-2, B-2, S-4, and W-3. This indicates that sub-basins which drain portions of the Oak Ridges or the Oak Ridges and the Till Plain are characterized by a high baseflow component, whereas basins which drain portions of the Till Plain and the Lake Iroquois Plain are characterized by a low baseflow component.

Ground Water Recharge

Recharge is the process by which the ground water is replenished and it involves the vertical leakage of water through the soil and sub-soil deposits to the saturated zone. The major sources of recharge in the study area are rain and snowmelt. The amount of recharge is irregularly distributed in time and space. Most recharge occurs during the spring and late fall months when evapotranspiration is small and soil moisture is maintained above field capacity by snowmelt or frequent rains. During the summer and early fall months, most of the rain is utilized to satisfy the evapotranspiration demands and to reduce the soil moisture deficiency, with little water left for recharge. During the winter months most of the precipitation is accumulated in the snowpack and recharge is negligible and confined to periods of minor heat spells when rain falls and snowmelt is generated.

The amount of recharge varies from place to place and it is controlled by the permeabillity and thickness of the soil and sub-soil deposits, the soil moisture content; the topography vegetal cover, land use, and depth to water table; the intensity, duration, and distribution of precipitation, and the form of precipitation as rain or snow.

From the foregoing, it is evident that the computation of the ground water recharge rates in time and space is an extremely difficult task which requires essentially complete knowledge of the climate, physiography, geology and land use of the study area. Because it is not possible to attain such detailed information, simple methods have to be used to estimated the time and space variability of recharge. The results of these methods, however, should be regarded, at best as rough estimates.

Two methods were employed in this report to arrive at estimates of the monthly and annual ground water recharge amounts for various basins and sub-basins in the study area. The first method is geohydrological and the second is hydro-meteorological.

The Geohydrologic Method - This method was outlined in detail in the section entitled: "The Coefficients of Hydraulic Conductivity, Transmissivity and Storage." In applying this method, the following steps were undertaken:

1 - A number of inventory periods were selected for each watershed during the winter season which satisfy conditions of no rain or snowmelt and negligible evapotranspiration. Under these conditions it is possible to assume that streamflow consists mainly of baseflow and recharge is nil.
2 - The mean change in the ground water level throughout each watershed of interest was determined for the selected inventory periods, and also on a monthly basis from data on shallow observation wells.
3 - The amounts of ground water discharge were estimated from baseflow analyses for every watershed of interest during each inventory period, and also on a monthly basis.
4 - An estimate of the mean storage coefficient in a watershed was made for each selected inventory period by solving the continuity equation of the form:

$$D = dH \times S \tag{16}$$

where: D = baseflow during inventory period (mm),
dH = mean change in ground water level within a watershed during the inventory period (mm),
S = estimate of the mean storage coefficient for the watershed (dimensionless).

5 - The obtained estimates of the mean storage coefficient of the watershed from its selected inventory periods were then averaged and the obtained value was assumed to represent the mean storage coefficient of the watershed.

6 - The monthly ground water recharge amounts were estimated by solving the continuity equation of the form:

$$R - D = dH \times S \tag{17}$$

where, R = Monthly ground water recharge (mm),
D = Monthly baseflow (mm),
dH = Monthly mean change in ground water level throughout the watershed (mm),
S = Mean storage coefficient of the watershed (dimensionless).

The geohydrologic method for the estimation of the monthly ground water recharge amounts is attractive, as neither data on soil moisture storage nor assumptions regarding the mechanism of the recharge process are required. To apply this method to a certain watershed under Canadian conditions, however, snowmelt calculations have to be performed in order to select proper inventory periods, baseflow analyses have to be made to estimate the ground water discharge, and an adequate number of shallow observation wells is required to estimate the mean change in the ground water level throughout the watershed. As most of the shallow observation wells in the study area are located within the Wilmot Creek basin, the method was applied to this basin and to all the sub-basins it includes.

The Hydro-Meteorologic Method - This method attempts to analyze the whole water balance within a watershed for a specified period of time starting with precipitation, rain and snowmelt, surface runoff, ground water runoff (baseflow), actual evapotranspiration, change in soil moisture storage and change in ground water storage.

To estimate the ground water recharge amount during a period of one month in a watershed by this method, the following steps were undertaken:

1 - The amount of moisture input (rain and/or snowmelt) to the watershed was determined.

2 - The amount of direct surface runoff from the watershed was assumed to be equal to the total runoff minus baseflow.

3 - The available moisture was assumed to be equal to the moisture input minus direct surface runoff.

4 - The available moisture was utilized first to satisfy the evapotranspiration demand. Three cases could be encountered at this point:

    a - The available moisture is more than the evapotranspiration demand. In this case, the excess water was defined as the available moisture minus the evapotranspiration demand. The excess water was then added to the soil moisture storage to satisfy any experienced deficiency. When the soil moisture deficiency was satisfied, the remaining water was assumed to percolate to the ground water storage as recharge. The change in ground water storage in this instance was assumed to be equal to the difference between recharge and discharge (baseflow). If the excess water, however, was less than or equal to the soil moisture deficiency, this excess water was added to the soil moisture storage and no recharge took place. The ground water storage in this case was decreased by an amount equal to the baseflow.

b - The available moistu
evapotranspiration demand. In this case, the whole available moisture was used to satisfy the evapotranspiration demand and no change in soil moisture storage or recharge took place. The ground water storage, however, was decreased by an amount equal to baseflow.

c - The available moisture is less than the evapotranspiration demand. In this case, the evapotranspiration demand was met by the available moisture as well as by water drawn from the soil moisture storage. Again, no recharge took place; the soil moisture storage was decreased by an amount equal to the evapotranspiration demand minus the available moisture, and the ground water storage was decreased by an amount equal to baseflow.

From the foregoing, it is clear that the hydro-meteorological method is based on the solution of the hydrologic budget equation where the input (rain and snowmelt) is used to generate direct runoff and to satisfy the evapotranspiration demands. Any surplus water is allocated first to soil moisture storage and the rest to the ground water as recharge, whereas any deficiency is compensated for by the soil moisture storage. The computations are straight forward and require data on rain and snowmelt, surface runoff, baseflow, and actual evapotranspiration. The method deals only with the changes in both the soil moisture and ground water storages.

Table 30 gives a comparison between monthly and annual ground water recharge as estimated by the geohydrologic method and the hydro-meteorologic method for the Wilmot Creek basin and its sub-basins. The table indicates the following:

1 - Estimates of the annual ground water recharge by both methods are, with a few exceptions, very close.

2 - Both methods show that most of the recharge occurs during the spring and late fall months (March, April, May, November, and December); less recharge occurs during January and February months, and little or no recharge occurs during the months of June, July, August, September and October.

3.- The recharge amounts during the months of March and April are of the same magnitude most of the time, according to the geohydrologic method; whereas the recharge in April is much higher than that in March most of the time, according to the hydro-meteorolgic method.

4 - Some recharge occurs nearly every month during the period June - October, according to the geohydrologic method; whereas no recharge is indicated by the hydro-meteorolgic method.

The fact that both methods gave the same magnitude for the annual ground water recharge most of the time, inspires a certain confidence in these results. The monthly recharge amounts as computed by both methods, however, differ most of the time, although their general distribution appears to be similar. It is recognized that both these methods give rough estimates of the monthly ground water recharge, and it is hoped that the true values of monthly recharge lie between them.

Table 31 gives the monthly and annual hydrologic budgets for various basins and sub-basins in the study area. The table includes for each basin and sub-basin, on a monthly and annual basis, information on precipitation, rain and snowmelt, surface runoff, ground water runoff (baseflow), actual evapotranspiration, change in ground water storage, and change in soil moisture storage. Table 31 indicates that the higher rates of ground water recharge occur within those sub-basins which drain parts of the Oak Ridges (i.e. W-1, W-2, S-2, S-3, B-2, B-4), whereas the lower rates of recharge occur within those sub-basins which drain parts of the Lake Iroquios

Plain (ie. W-3, and S-4). Based on these results, it is possible to conclude that the annual ground water recharge within the Oak Ridges physiographic unit is in the range of 280 - 380 mm; within the Till Plain physiographic unit, it is in the range of 150 - 200 mm, and within the Lake Iroquois Plain physiographic unit it is in the range of 50 - 100 mm.

One more important conclusion could be made based on Table 31 with regard to the change in the soil moisture storage. It appears that the change in the soil moisture storage within a calendar year, January - December, is zero for all the basins and sub-basins under consideration. This result should be expected for Ontario conditions, where the frequent rains in the fall restore the moisture content in the soil to or above field capacity level. The implication of this observation is important, specifically in the computation of the annual hydrologic budget, where any change in storage could be attributed normally to a change in the ground water storage if a calendar year is used as the basis for computation.

GROUND WATER MODELLING

Simulation of Ground Water Flow

Simulation of ground water flow by mathematical models is a process which represents the essence of the physical flow system. The use of such models helps to improve the understanding of the real hydrogeologic system as they incorporate virtually all available pertinent information about and show how the whole system acts. In addition, once these models are calibrated, they can be used to predict the response of the system to withdrawals or artificial recharge. New plans for withdrawal or proposals for recharge can be readily evaluated by merely changing the locations or rates of withdrawal and/or recharge in the model. Thus, these models can be used as management tools to evaluate the effects of alternative methods of controlling or developing the ground water resources in an area of interest.

The Basic Ground Water Flow Equation Used in Two-Dimensional Ground Water Models

Ground water is subject to continuous movement, the rate of which is a function of the hydrogeologic material in which it moves, and the existing hydraulic gradients. The fundamental nonlinear partial differential equation governing the unsteady, two-dimensional ground water flow is based on Darcy's Law and the Law of Conservation of Mass and may be written as:

$$\frac{\delta}{\delta x}\left[T_{(x,y)}\frac{\delta h}{\delta x}\right]+\frac{\delta}{\delta y}\left[T_{(x,y)}\frac{\delta h}{\delta y}\right]=S_{(x,y)}\frac{\delta h}{\delta t}\pm Q_{(x,y,t)} \qquad (18)$$

(Bittenger et al, 1967)

where $T_{(x,y)}$ is the transmissivity, L^2/T; $h_{(x,y,t)}$ is the hydraulic head, L; $S_{(x,y)}$ is the storage coefficient (dimensionless); (x,y) are the rectangular coordinates; t is time, T; and $Q_{(x,y,t)}$ is the volume flux per unit area, L/T. The flux term may represent pumpage from or recharge to the system, or stream gains and losses.

Equation 18 forms the basis for many deterministic two-dimensional ground water simulation models. Because this equation has no general analytical solution, these models utilize numerical finite element or finite difference methods which yield approximate solutions for the equation, provided that proper sets of boundary and initial conditions, and reasonable distributions for the transmissivity, storage and flux are given. These solutions constitute distributions of the hydraulic head throughout the area of interest, at given time steps.

From the foregoing, it is clear that in order to predict the time variations of ground water levels in an area by a ground water model, the following basic, five types of data have to be obtained:

1. transmissivity function T;
2. storage function S;
3. flux function Q;
4. ground water level initial conditions;
5. boundary conditions.

The application of ground water models to aquifers of limited dimensions is a simple procedure because all the required data are either available or can be assembled within an acceptable frame of time, cost and manpower.

The application of these models, however, to study regional ground water flow systems in a basin is a completely different matter. In such a case, the collection of the required ground water system parameter values in a sufficiently dense space-time network, can be prohibitively expensive. For this reason, most of the parameter values are deduced from the behaviour of the system, rather than by direct measurement or observation. Hence, the best test of a ground water model, when applied to analyze regional ground waer flow systems, is the general pattern of the steady state hydraulic head distribution, as well as the general pattern of water

level variations for the dynamic, unsteady case. If the model fails to produce such results reasonably, then the estimates of one or all of the hydrogeologic parameter values are in error, which brings into focus the concept of calibration.

Calibration of Ground Water Models

The main method of testing the accuracy of a digital ground water model is to simulate historical conditions (i.e. ground water levels in a number of observation wells) and compare the response of the model to that measured in the field. This process is known as calibration. A great deal of caution should be exercised by the hydrologist in the process of calibrating a ground water model because it is possible to obtain an excellent fit between the response of the model and the observed heads in a number of observation wells, simply by changing arbitrarily the values of the hydrogeologic parameters in the vicinity of these wells. Obviously, an infinite number of combinations could lead to an "excellent fit" and the process of "calibration" would become meaningless.

A close examination of Equation 18 reveals the hidden pitfalls that are associated with the process of calibrating a ground water model. This equation describes the unsteady, two-dimensional ground water flow in an aquifer. Its solutions are sets of hydraulic head distributions for a number of time steps that are determined by the combined effects of the initial and boundary conditions, spatial distributions of transmissivity and storage and space-time distributions of the flux. This implies that the simulated hydraulic head variations for a point (observation well) within the modelled system are dependent on the transmissivity and storage coefficient values assigned to that point, the initial hydraulic head value at the point when the simulation starts, the time variation of recharge at the point and also the boundary conditions assigned to the whole system. Assume now, that the simulated hydraulic head at the point of interest is completely different from its measured historical record and the objective is to close the gap between the two. What hydrogeologic parameter should be changed and by how much? Unfortunately, the answer to this question is not

simple because different changes in the values of various parameters could produce the same desired result. For example, to reduce the amplitude of water level fluctuations at a point, one might increase the value of transmissivity, increase the value of the storage coefficient or decrease the amount of recharge. The question now is: what course has to be followed? The only answer to this question in applied hydrogeology, where the measurements of hydrogeologic parameters are not entirely adequate, is to accept parameter values which are deemed to lie within a reasonable range. There is nothing wrong with this limitation if, indeed, this estimated range of "reasonable values" is based on sound judgement. In any case, the calibration procedures are rarely applied in an entirely rational way and might be tinged sometimes with a heavy dose of personal judgement. Because of this inherent bias in calibration procedures, they should be used only to apply minor corrections to independently measured parameter values.

The calibration procedures may be simplified and made more rational when ground water models are applied to gauged basins that are under natural conditions, where the ground water flow is from the divide towards the streams. For such basins, it is reasonable to assume that the long term, mean, ground water recharge is equal to the long term, mean, ground water discharge (baseflow), that the change in storage is zero and that the ground water flow is under steady state. This assumption neglects evapotranspiration losses in the discharge zone. A ground water model, which is based on Equation 18, could be forced to simulate the steady state ground water flow in a basin, by assuming that the net flux to and from the basin is equal to zero (i.e. recharge = discharge). An assumption of a steady state ground water flow implies that the hydraulic head at any point within the system is not a function of time. This means that the time derivative of the hydraulic head, h/ t, in Equation 18, is equal to zero and consequently the whole term involving the storage coefficient in the equation is equal to zero. Hence, the solution of the equation becomes independent of time and of the storage coefficient. Furthermore, because the solution is independent of time, it is also independent of the initial conditions. It follows, therefore, that the steady state solution

depends only on the transmissivity distribution, the recharge distribution (constant in time and variable in space) and the boundary conditions. Thus, the ground water model will reproduce a steady state water level distribution map which will be similar to the mean water level map for the basin, derived from actual observations, if the transmissivity, boundary conditions and the ground water budget have been adequately described.

The boundary conditions in basins under natural conditions, where the ground water flow is from the divide towards the streams, can be adequately approximated. This reduces the calibration process to the verification of the transmissivity and recharge distributions. Even at this stage, the calibration of a ground water model is not an easy task and should be based on sound hydrologic judgement and better, if available, on additional hydrologic data.

Once the calibration of the steady state case is completed, the reproduced water level map, the boundary conditions and the verified transmissivity distribution, can be used, along with a storage coefficient distribution and variable recharge in time and space, to simulate the unsteady ground water flow. The calibration of the unsteady case is then reduced to verification of the storage coefficient distribution and the variable recharge rates. Again, the calibration has to be made with prudence and be based on sound hydrologic judgement.

Experience in calibrating ground water models shows that there is no substitute for sound hydrologic and hydrogeologic data. The "calibrated" set of hydrogeologic parameters is not necessarily a true image of the parameters of the real system, rather it is a set which yields the best fit with observed records. The usefulness of models in the study of the regional ground water flow problems, however, is tremendous because they incorporate all the available information pertinent to the modelled system, they verify the perception of the system and point out those areas where additional data are required.

Selection of Ground Water Model

At present, a large number of ground water models is available in the literature and all these models try to solve the basic one, two, or three-dimensional ground water flow equation. The main difference among these models is related to the type of numerical solution (finite element or finite difference) used to formulate the basic equations of ground water flow. Minor differences are related to the type of ground water problems being solved, the number of options available and the input-output formats.

For the purpose of this study, a composite digital computer program that can simulate one, two, or three-dimensional steady and unsteady flow of ground water in heterogenous aquifers under water table, nonleaky and leaky artesian conditions, was assembled from programs written by Prickett and Lonnquist (1971). A finite difference approach is used in the model to formulate the equations of ground water flow. This involves the replacement of the continuous aquifer system by an equivalent set of discrete nodes; a modified, alternating direction, implicit method then solves the set of resulting finite difference equations. The composite model includes time varying pumpage from wells, natural or artificial recharge rates, the relationship between surface water and the ground water reservoir, the mechanism of converting from artesian to water table conditions, variable grid spacing, and a check on the water balance. In addition, the model includes 14 options related to the type of output desired. Detailed discussions of the necessary mathematical background, documented program listings, job setup procedures, theoretical versus computer comparisons, and field examples are given by Prickett and Lonnquist (1971).

Ground Water Modelling of Wilmot Creek Basin

As most of the observation wells in the study area are located within the Wilmot Creek basin, it was selected for the application of the ground water model. The objective of modelling this basin was to evaluate the estimates of the hydrogeologic parameters and the ground water discharge and recharge rates obtained in the previous sections by conventional techniques.

Analysis of the complex stream-aquifer system in the Wilmot Creek basin was accomplished by subdividing the basin into a large number of cells which constitute a finite difference grid. Figure 26 is a map of the study basin showing the finite difference grid (51 rows x 43 columns) of variable spacing that was imposed upon the system. In addition, the map shows the designated stream nodes, the location of observation wells, the location of the streamflow gauging stations and the transmissivity distribution assigned to the basin.

For a successful simulation of the dynamic response of ground water to natural stresses in the Wilmot Creek basin, a number of assumptions were made:

1. The Wilmot Creek basin is a hydraulically continuous system in which the ground water flow is two dimensional. The upper boundary of the system is the water table, and the lower boundary is an assumed horizon within the bedrock, beneath its upper 15 m. The system is bounded on all sides by the ground water divide which coincides with the topographic divide.

2. The ground water basin can be replaced by a two-dimensional, variable spaced node network which can be used to spatially define the input-output relationships.

3. The transmissivity and the storage coefficient at each node remain constant in time.

4. The ground water evaporation, utilization (pumpage and irrigation) and subsurface underflow are negligible.

5. Wilmot Creek and its tributaries have a good hydraulic connection with the ground water system. Stream nodes are designated to represent the creek. At each stream node, a stream bed leakage factor is assigned a value relative to the order of the stream, and the hydraulic head at each stream node is assumed to remain constant in time.

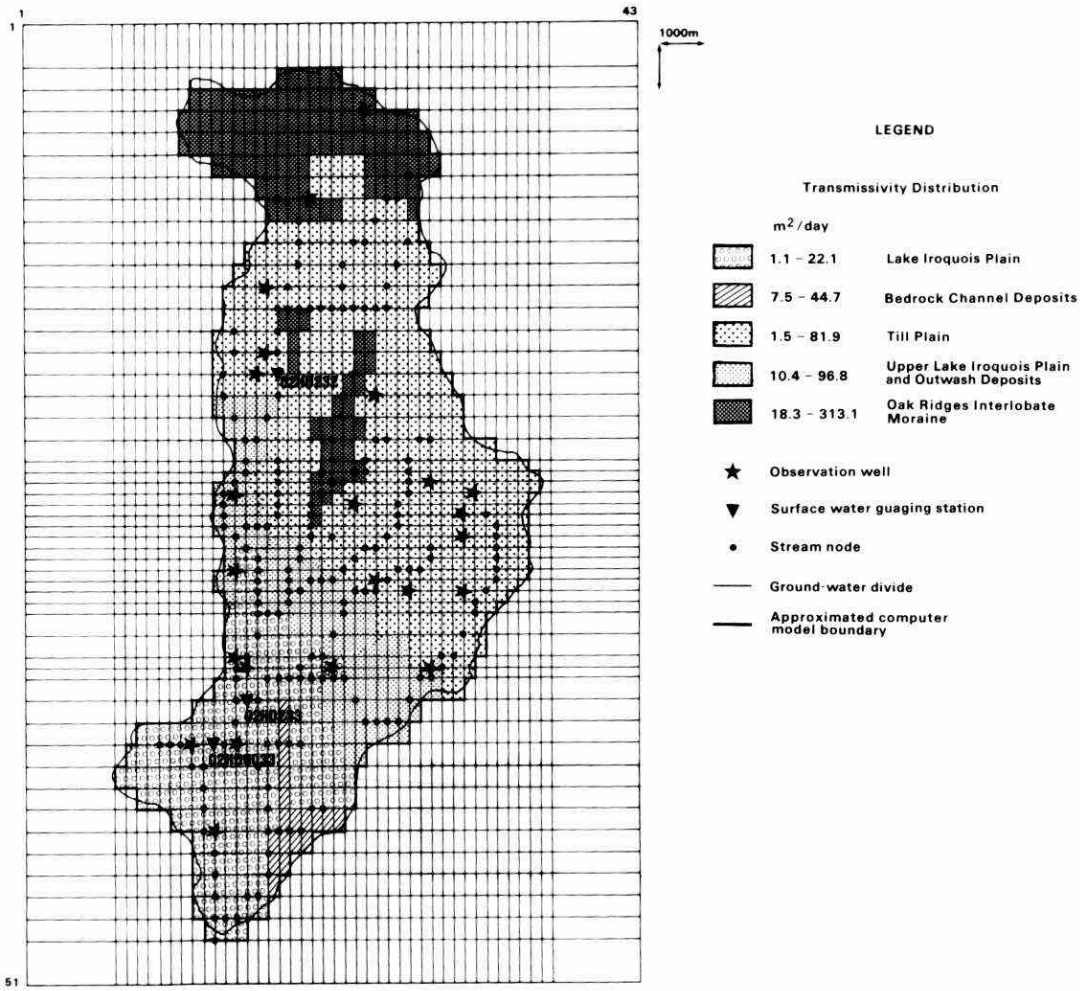


Figure 26. Finite Difference Grid Used To Model The Wilmot Creek Drainage Basin.

Mathematically, the interaction between the stream and the aquifer was described by a stream bed leakage factor (1/T) expressed as:

$$LF = \frac{KxLgxW}{MxAn} \tag{19}$$

where K is the hydraulic conductivity of the streambed, (L/T); Lg is the length of the stream reach associated with a stream node, (L); W is the mean width of the stream reach, (L); M is the average thickness of the stream bed, (L); and An is the area associated with the stream node, (L^2). The discharge of the aquifer into the stream is expressed as:

$$Q = dhxAnxLF \tag{20}$$

where Q is the ground water discharge at the stream node, (L^3/T); dh is the head difference between the level of water in the stream and that in the aquifer under the stream bed, (L).

Substituting Equation 19 in Equation 20 results in:

$$Q = dhxLgxWxK/M \tag{21}$$

Assuming that the area of the streambed is As = LgxW, then Equation 21 reduces to:

$$Q = dhxAsxK/M \tag{22}$$

Equation 22 indicates that the ground water discharge to the stream is directly proportional to the stream bed area, the hydraulic conductivity of the stream bed, and the head difference between that of the aquifer and the stream; it is inversely proportional to the stream bed thickness.

The width of Wilmot Creek ranges between 3 m and 9 m. No data were available on the thickness and the hydraulic conductivity of the stream bed material. Therefore, a uniform thickness of 0.15 m and a uniform hydraulic conductivity of 0.02 m/day were assumed in the calculation of the stream bed leakage factors assigned to various stream nodes.

The assigned leakage factors ranged from 0.01 to 0.15 over one day, which represents good hydraulic connection between the creek and the aquifer system.

Data Requirements

The data requirements for the ground water model are the hydrogeologic parameters and the initial and boundary conditions. The transmissivity, storage coefficient, recharge rates and initial hydraulic head must be specified at each node. In addition, boundary nodes and stream nodes must be specified. In total, about 12,000 items of input data must be supplied.

Hydrogeologic Parameters

Estimates of transmissivity were made for 45 bedrock wells and 340 overburden wells within the Wilmot Creek basin. These estimates were based on the mean hydraulic conductivities calculated for the sand, till, limestone and shale from data on 104 pumping and recovery tests (see section on: The Coefficients of Hydraulic Conductivity, Transmissivity and Storage). These data have been extrapolated to cover the entire Wilmot Creek basin. The regionalization of the transmissivity data was based on the geologic structure of the basin, data trends and data averages.

The transmissivity values for the Wilmot Creek basin ranged from 1.1 to 313.1 m^2/day. These values were distributed according to geology as given in Table 32.

Table 32. Assumed Transmissivity Distribution According to Geology in the Wilmot Creek Basin.

Geological Unit	$T(m^2/day)$
1. Lower Lake Iroquois Plain	1.1 - 22.1
2. Bedrock Channel deposits	7.5 - 44.7
3. Upper Lake Iroquois Plain and outwash deposits	10.4 - 96.8
4. Till Plain	1.5 - 81.9
5. Oak Ridges interlobate moraine	18.3 - 313.1

The estimated transmissivity values and their regionalization through extrapolation are believed to be reasonable and no attempt was made to change them during further calibration.

As was mentioned earlier, available data on pumping and recovery tests did not allow for the determination of the storage coefficients. A hydrogeologic method which is based on the equation of continuity, was used to arrive at estimates of the mean storage coefficient values for all the sub-basins within the Wilmot Creek watershed. A detailed description of this method is given in the section entitled: The Coefficients of Hydraulic Conductivity, Transmissivity and Storage.

Four values were computed as the mean storage coefficients for sub-basins: W-1, W-2, W-3 and local area (LA). These values were 0.060, 0.037, 0.003 and 0.011, respectively. The above values were then distributed with minor alterations according to geology throughout the Wilmot Creek basin as listed in Table 33.

Table 33. Assumed Storage Coefficient Distribution According to Geology in the Wilmot Creek Basin

Geological Unit	S (dimensionless)
1. Lower Lake Iroquois Plain	0.003
2. Bedrock Channel deposits	0.003
3. Upper Lake Iroquois Plain and outwash deposits	0.040
4. Till Plain	0.010
5. Oak Ridges interlobate moraine	0.060

It was recognized from the outset that the accuracy of the storage coefficient distribution is highly uncertain. Therefore, special attention was paid to adjust the storage coefficient values during the calibration of the model.

One of the assumptions for the simulation was that the ground water evaporation, utilization and subsurface underflow were negligible. Therefore, the input to the system consists of natural recharge and the output is in the form of natural discharge (baseflow).

Two sets of recharge rates were used to simulate the steady and the unsteady ground water flow in the Wilmot Creek basin. The first set (steady state case), was built into the model by assigning to each node, within each sub-basin, a constant monthly recharge rate derived from the long term means of annual ground water recharge as computed by the hydrogeologic method (Table 30) for the period (October, 1967 - September, 1972). Hence, constant recharge rates in time and variable only in space, were used for the steady state case. The second set (unsteady case) was built into the model by assigning to each node, within each sub-basin, a variable monthly recharge rate as computed by the hydrogeologic method (Table 30) for the period (October, 1967 - September, 1972). Hence, variable recharge rates in time and space were used for the unsteady case.

Ground water discharge is computed by the model at each stream node and the amounts are routed downstream by adjusting the total outflow at successive nodes in a downstream direction. This facilitates the computation of the ground water discharge at various streamflow gauging stations and allows for a comparison between the model computed values and the values obtained through streamflow separation.

Initial and Boundary Conditions

An initial hydraulic head must be assigned to each node in the aquifer system being modelled. The initial head distribution can be arbitrary when modelling a steady state solution because this solution is independent of initial conditions. However, the unsteady state solutions for different time steps depend on the initial conditions, and an accurate initial head distribution must be specified.

A steady state ground water level map for the Wilmot Creek basin was constructed from averaged data available from the observation well network, along with water level data of 280 wells on file with the Ministry of the Environment (Figure 27). The accuracy of the computer generated steady state solution was tested and verified against the manually prepared ground water level map for the Wilmot Creek basin. The verified steady state solution then becomes the initial condition for the solution of the unsteady state problem.

As was stated earlier, the ground water divide for the Wilmot Creek basin was assumed to coincide with the topographic divide. The ground water divide, which is by definition a boundary across which there is no flow of water, was formed in the model by assigning zero transmissivities and zero recharge rates for nodes outside the boundaries of interest.

Simulation Results, Calibration and Conclusions

Ground water modelling of the Wilmot Creek basin proceeded in the two phases: a steady state phase and an unsteady state phase.

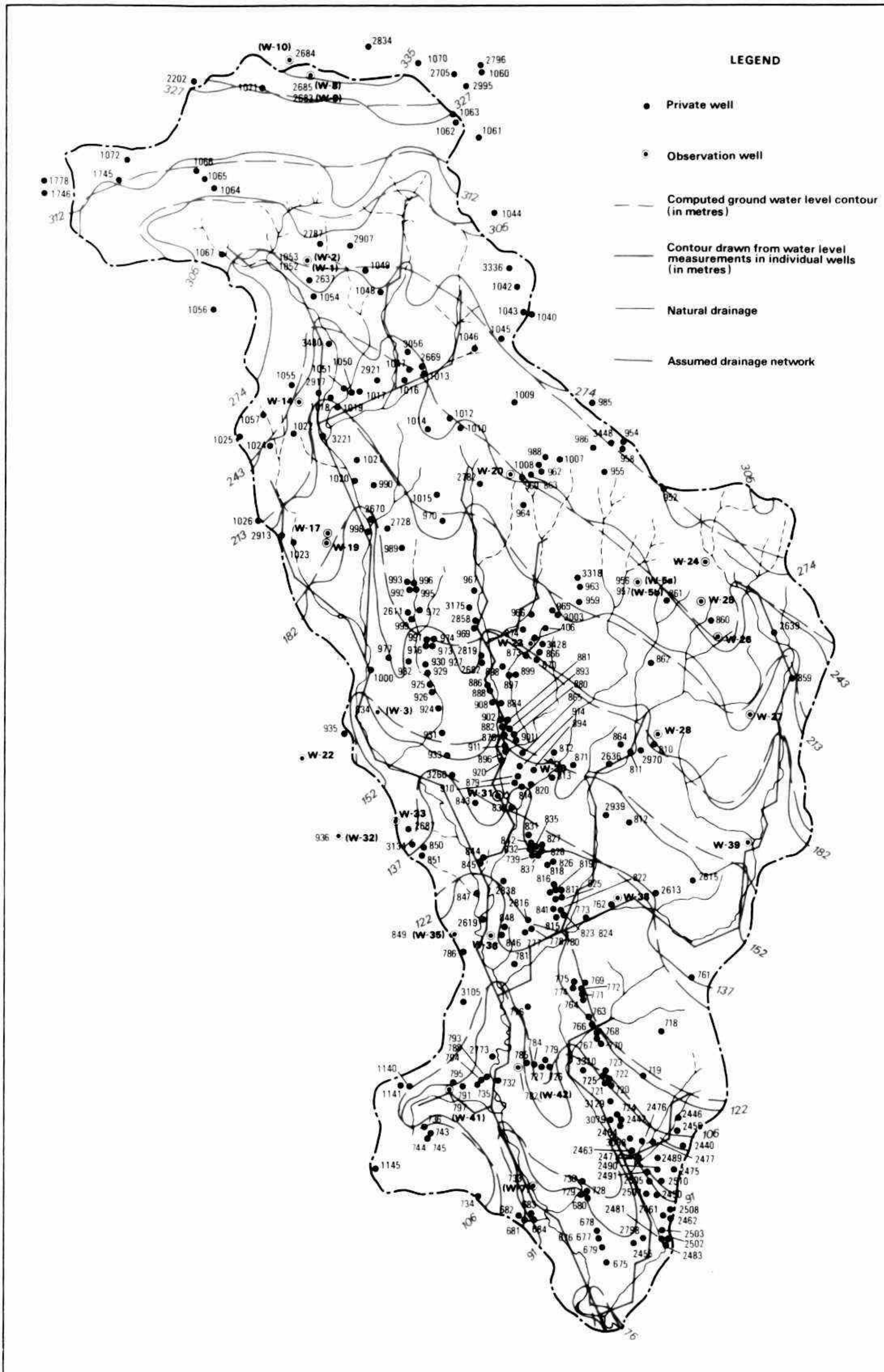


Figure 27. Comparison of computed and measured ground water levels (steady state case) in the Wilmot Creek drainage basin.

The steady state solution for the Wilmot Creek basin was obtained using the transmissivity distribution and the boundary conditions shown in Figure 26. An arbitrary value of 193 m, which is close to the mean ground water level elevation in the basin, was assigned as the starting hydraulic head at all the nodes.

Initially, a constant recharge rate of 17 mm per month was distributed uniformly over the whole Wilmot Creek basin. This recharge rate is equivalent to an annual recharge of 204 mm which represents the long term mean annual recharge for the area above the federal gauge 02HD009 (Table 30). The obtained steady state solution, however, showed unrealistically high ground water levels for the lower part of the basin and low ground water levels for the upper parts of the basin. One might have expected such a result because the mean long term recharge rate is different from one location to another. Indeed, the simulation improved drastically by varying the recharge rates in space, based on the long term mean annual recharge computed for sub-basins W-1, W-2, W-3 and local area (LA). Because sub-basin W-1 is part of sub-basin W-2, and the long term means of the annual recharge are close for both sub-basins, a constant recharge rate of 28 mm per month was assigned to all the nodes above gauging station W-2. Nodes within the local area (LA) were assigned a constant recharge rate of 14 mm per month, whereas nodes within sub-basin W-3, and below gauging station 02HD009, were assigned a constant recharge rate of 7 mm per month.

Figure 27 shows a comparison between the simulated and measured ground water levels for the steady state case. The figure indicates that the general pattern of ground water level distribution throughout the basin was successfully generated within $\pm$ 8 m. The modelled ground water discharge at the federal gauge 02HD009 was 191 mm per year, compared to a long term mean annual baseflow of 204 mm.

The differences between the computed and measured steady state ground water level distributions are due to simplifying assumptions inherent in the modelling procedure, approximation of the shape of the ground water divide boundary and of the surface drainage pattern, and inevitable errors in the transmissivity and recharge distributions. Nevertheless, the computed steady state solution indicates that both the transmissivity and recharge distributions computed by conventional methods and input to the model are reasonable. Therefore, no further improvement on the solution through additional calibration was considered necessary.

The unsteady state phase for simulating the transient ground water flow in the Wilmot Creek basin proceeded using the same transmissivity distribution and boundary conditions as for the steady state phase. Also, the hydraulic head distribution obtained from the steady state solution was used as initial conditions for the solution of the transient problem. In addition, each node within each sub-basin was assigned a variable monthly recharge rate as computed by the hydrogeologic method (Table 30), and each node within each geologic unit was assigned a storage coefficient as given in Table 33.

The hydraulic head elevations throughout the study area were computed for the end of each month of the simulation period, October, 1967 - September, 1972. These elevations were compared with field data on observation wells to calibrate and verify the model.

Two problems were encountered during the initial runs of the dynamic model:

1. A significant discrepancy up to 8 m between the initial observed and computed levels was encountered at eight observation wells, whereas a minor discrepancy up to 3 m was encountered at the other observation wells.

2. The simulated hydraulic head fluctuations at all the observation wells were either smaller or larger than those measured.

The nature of the first problem is inherent in the modelling procedure and little can be done to alleviate it. The fact is that the water level elevations are computed for the nodes of the finite difference grid and in order to simulate the water level variations at a well, its position has to be shifted to the nearest node. This introduced positional error accounts for most of the discrepancy encountered between the initial observed and computed levels.

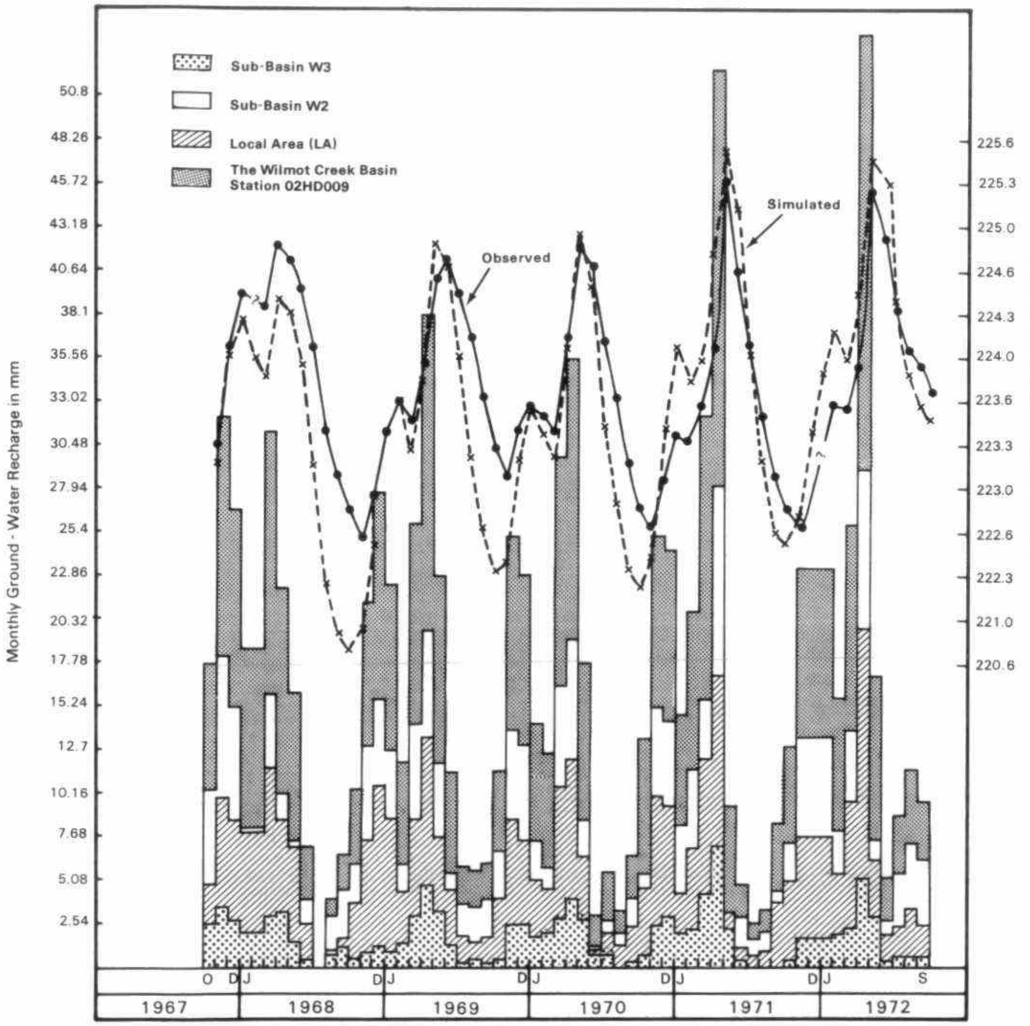


Figure 28. Variations of Ground Water Recharge in Sub-Basins W2 and W3 and Local Area (LA) Relative to the Total Recharge of the Wilmot Creek Basin. Also, a comparison between Measured and Simulated Ground Water Level Variations in Well W-5 for the period 1967 - 1972.

The second problem could be due to erroneous transmissivity, recharge rates or storage coefficient values assigned to nodes surrounding the modelled well. Because of the scarcity of data on the storage coefficient distribution, a subjective decision was made to attribute the whole error in the magnitude of water level fluctuations to the assigned storage coefficient values. It was found that a change of up to ± 50 percent in the value of the storage coefficient, at the nodes surrounding most of the observation wells, was needed to significantly improve the computed water level fluctuations.

The agreement between observed and computed water level fluctuations improved with increasing simulation time. The observed ground water level fluctuations during the study period varied from 0.35 to 3.53 m and averaged 1.81 m, whereas the difference between observed and computed levels was within 0.30 m for 16 of 24 observation wells (Figure 28).

The estimated monthly recharge rates were reasonable most of the time, with the exception of certain summer months, where these rates seemed to be somewhat underestimated.

Table 34 gives a comparison between monthly and annual ground water discharge, as simulated by the ground water model and estimated from baseflow analysis for federal station 02HD009. This table indicates that the simulated annual ground water discharges and estimated annual baseflows are in close agreement, with the simulated values being consistently lower. However, the simulated monthly ground water discharges show less variation than the estimated monthly baseflows.

SUMMARY AND CONCLUSIONS

1. The hydrogeologic regime of the Bowmanville, Soper and Wilmot creeks drainage basin was studied as part of the IHD program. This drainage basin is located in southern Ontario on the north side of Lake Ontario between Longitudes 78^{0} 35' and 78^{0} 51' W and Latitudes 43^{0} 53' and 44^{0} 04' N. The basin has an area of about 270 km^2 with land surface elevations ranging from 74 m at Lake Ontario to about 375 m in the extreme northeastern parts. It includes three major physiographic units: the Iroquois Lake Plain, the Till Plain (the South Slope), and the Oak Ridges interlobate moraine.

2. The bedrock in the study area is obscured by overlying deposits of glacial drift. Black shales of the Whitby Formation from the Nottawassaga Group are present in the western part of the study area, while dark, bituminous limestones of the Lindsay Formation, from the Simcoe Group, subcrop throughout the rest of the area. According to Liberty (1969), the Whitby Formation is Upper Ordovician in Age, whereas the Lindsay Formation is Middle Ordovician in Age.

3. The overburden within the study area consists of glacial, glacio-fluvial and glacio-lacustrine deposits of Pleistocene Age, with minor amounts of alluvial, swamp and bog deposits of Recent Age.

4. Seven major stratigraphic units were identified within the Pleistocene section. These units are:

   i a Proglacial Lake Unit consisting mainly of varved clay;
   ii an Upper Glacial Unit made up of two till sheets separated by glacio-fluvial sands and silts;
   iii a Middle Glacial Unit composed of till;
   iv The Clarke Deposits Unit, consisting of a lower part of glacio-lacustrine clays and an upper part of glacio-fluvial sands;
   v a Lower Glacial Unit composed of till;
   vi a Lower Glacio-fluvial Unit composed of sand;
   vii a Basal Glacial Unit composed of till.

5. The climate of the study area is characterized by warm summers, mild winters, a long growing season with usually reliable rainfall. It is influenced by the proximity of Lake Ontario.

6. The mean monthly temperatures in different parts of the study area are very similar during the spring and fall periods. The lowest mean monthly temperature is observed during the winter season in the months of January or February. In this season, however, temperatures registered in the lower parts of the basin near Lake Ontario are 1 to 2^{o}C higher than those registered in the upper parts of the basin. The highest mean monthly temperature is recorded during the summer season in the months of July and August. In this season, temperatures registered in the lower parts of the basin are 1 to 2^{o}C lower than those registered in the upper parts of the basin. This reflects a very definite moderating influence due to Lake Ontario in the lower parts of the basin. Temperature data from the Orono station, located centrally in the Police Village of Orono, can be used as an approximation of the long term temperature variations within the study area. The 30 year (1941-1970) normal annual temperature at this station is 6.94^{o}C, with a maximum temperature of 39.44^{o}C recorded on July 10, 1936 and a lowest temperature of - 34.44^{o}C recorded on February 8, 1934.

7. Precipitation within the study area, mainly in the form of rain and snow, differs from one location to another and from one year to another. These differences reflect variations in topography, the proximity to Lake Ontario, the prevailing winds and the nature and frequency of the weather systems which cross the study area.

   In general, precipitation increases from the south along the Lake Ontrio shoreline towards the north. The lowest six-year mean annual precipitation during the period 1968-1973 was recorded at the Bowmanville STP station located in the lower end of the basin and equalled 773 mm. On the other hand, the highest six-year mean annual precipitation was recorded at the Leskard station located in the upper, northern end of the basin.

Hence, it is possible to conclude that the existence of an orographic barrier in the northern part of the basin (the Oak Ridges) exerts more influence on the long term trends of precipitation than does the proximity to a moisture source (Lake Ontario).

Precipitation data from the Orono station can be used as an approximation of the long term mean monthly and annual precipitation in the study area. The highest long term mean monthly precipitation for the period 1941-1970 was recorded during the month of July and equals 80 mm, whereas the lowest long term mean monthly precipitation was recorded during the month of September and equals 66 mm. The long term mean annual precipitation at this station, and for the same period, is 869 mm and is made up of 704 mm of rain and 1638 mm of snow.

8. During the winter season, a considerable part of the precipitation (up to 60%) falls in the form of snow and accumulates on the ground surface in a snowpack. This capacity of the snow to accumulate and then to melt early in the spring, affects all the hydrologic processes that take place within the study area.

   As in the case of precipitation, the amount of snowfall differs from one location to another and from one year to another. In general, however, the long term mean annual snowfall increases from the south, along the Lake Ontario shoreline, towards the north. For the available period of record (1968-1973), the total annual snowfall ranged from 488 mm recorded at the Mostert station (lower part of the basin), to 3045 mm recorded at the Happy Valley station (upper part of the basin).

9. The generation of snowmelt at a point location in a snowpack is essentially a thermodynamic process, the amount of melt produced being dependent on the heat exchange between the snowpack and its environment.

A simple snowmelt scheme known in literature as the degree-day method, was used to estimate the amount of daily snowmelt at nine precipitation stations in the study area. The validity of the method was tested against a more elaborate snowmelt scheme based on an energy balance approach, using the same data. A comparison between the results of both methods indicates that the degree-day method, despite its approximate nature, gives good results and provides accuracy of melt predictions comparable to those estimates obtained from the energy balance method.

Analyses of the snowfall, snow accumulation and snowmelt processes indicate that they modify greatly the effect of the precipitation input to the basin. It was found that the amount of rainfall and snowmelt during the months of November, December, January, February, and sometimes March, is less than the total precipitation input. On the other hand, during the months of March and frequently April, the amount of rainfall and snowmelt is much larger than the precipitation input. The large amount of water that is released due to snowmelt during March and April, generates high flows and sometimes floods and contributes substantially to the ground water storage through recharge.

10. Nineteen classes of soils are present within the study area (Webber and Morwick, 1946). These soils range in texture from clay loam to sand; their drainage varies from very poor to excessive; their wilting points range from 4.8 to 12.8% and their field capacities range from 15.1 to 50.0%.

11. The zone of soil moisture is at a critical juncture in the hydrologic cycle. The availablility of water in this zone affects the infiltration process, the transmission of water laterally as interflow or vertically as ground water recharge, the evaporation of the stored soil moisture or its utilization by the plants, and the freeze-thaw cycles. Within the study area, precipitation is the primary source of water for soil moisture recharge, whereas evapotranspiration and gravity drainage are the primary mechanisms for soil moisture depletion.

Available data from neutron measurements of soil moisture content at 15 sites within the study area indicate that the soil moisture content is highest during the period of March to May, which reflects to the snowmelt period. Soil moisture depletes drastically during the period of June to September due to high evapotranspiration, mainly by plants, and recovers to field capacity conditions late in the fall.

Analyses of the hydrologic budgets for various basins and sub-basins in the study area indicate that it is safe to assume that the change in soil moisture storage is zero if the calculations are made for a calendar year, starting in January and ending in December.

12. Evapotranspiration is the combined evaporation from water, snow and soil surfaces and transpiration by vegetation. When the supply of water is non-limiting, evapotranspiration occurs at the potential rate. If the water supply is limited, actual evapotranspiration will fall short of potential evapotranspiration.

Estimates of monthly annual potential evapotranspiration within the study area were made using the Thornthwaite method (1948). The monthly estimates for the period 1968-1973 ranged from 0.0 to 129.3 mm, with highest values computed for the months of June, July and August. The annual potential evapotranspiration for the same period was estimated to range from 536.2 to 597.4 mm, with an annual mean of 574.2 mm.

The Holmes and Robertson moisture budget technique (1960) was used to estimate the monthly and annual evapotranspiration for various basins and sub-basins in the study area. The monthly estimates indicate that most of the actual evapotranspiration occurs during the period May to September with little or no actual evapotranspiration during the rest of the year. The six year (1968-1973) annual means of actual evapotranspiration for different basins and sub-basins in the study area range from 443.6 to 507.9 mm, which is 12 to 22% less than the six year annual mean of potential evapotranspiration.

13. Streamflow from the Bowmanville, Soper and Wilmot creeks drainage basin is typical of many basins in the Province of Ontario where the primary source of flow is snowmelt and ground water discharge.

Concurrent daily streamflow data, with a few exceptions, are available at 14 streamflow gauging stations in the study area, since January 1968. Analyses of streamflow records indicate the following:

i The highest daily flows occur during the period March to May as a result of the snowmelt process. Other high flows occur after severe summer and fall rainstorms. The lowest daily flows occur during the winter months: January and February, as well as during the summer months: June, August and September.

ii The variations of daily flow recorded at various gauging stations reflect the differences in physiography in various sub-basins within the study area. The least variations are observed at Station W-1, which drains part of the Oak Ridges interlobate moraine physiographic unit. Daily flows at this station vary little from one day to the next and the ratio of maximum to minimum daily flows recorded during the period 1968-1974 ranges from 2.60 to 6.55. The largest variations are observed at station W-3 which drains parts of the Till Plain and Lake Iroquois Plain physiographic units. The ratio of maximum to minimum daily flows recorded here during the same period ranges from 117 to 1189. The variability of daily flows at other stations within the study area is similar either to that of station W-1 or to that of station W-3; at some stations the variability is between these two extremes.

iii Monthly streamflows at all the stations exhibit, in general, the following pattern: a relative decline from January to February; a substantial rise during March and April; a continuous decline from May to September and a relative rise from October to December. Again, when the relative magnitudes of the changes of the monthly flow

pattern are considered, it is found that the monthly hydrograph for station W-1 is nearly flat with little variations from one month to another. The monthly hydrograph of station W-3 is characterized by sharp peaks and steep recessions, whereas the monthly hydrographs for all the other stations are somewhere between those of stations W-1 and W-3.

iv On a seasonal basis, it is possible to describe the runoff in the study area as following a two-peak - two-recession pattern. The two peaks occur during the spring and the fall, the first being high and the second being moderate. The two recessions occur during the winter and summer, the first being short lived and moderate and the second longer lived and steeper initially.

v The maximum total annual runoffs for the period (1968-1973) were observed at most stations during the year 1972 and ranged from 326.9 to 491.5 mm, whereas minimum runoffs were observed during the year 1970 and ranged from 228.3 to 404.3 mm.

vi The shape of the flow duration curve is determined by the hydrologic and geologic characteristics of the drainage basin. The more nearly horizontal the curve, the greater is the role of ground water discharge in sustaining the streamflow. The flow duration curve of sub-basin W-1 is nearly horizontal, indicating a significant ground water component in streamflow. The flow duration curves of sub-basins W-3 and S-4 are steep, which indicates a small ground water component in their streamflows. The flow duration curves for all the other sub-basins plot in intermediate positions between the curve of W-1 and the curves of W-3 and S-4.

14. From the foregoing it is apparent that three different streamflow regimes are operating within the study area.

These regimes are:

i The Oak Ridges interlobate moraine flow regime, which is characterized by a small direct surface runoff component, a significant ground water runoff component and small variations in daily streamflow from one day to the next.

ii The Till Plain flow regime, which is characterized by equally significant direct surface and ground water runoff components and moderate variations in daily streamflows.

iii The Lake Iroquois Plain flow regime, which is characterized by a significant direct runoff component, a small ground water runoff component and significant variations in daily streamflows.

The flow regimes at many gauging stations in the study area are mixed and contain elements of the flow regimes described above.

15. The rate of yield of ground water to wells within the bedrock is controlled by the distribution and size of fissures, joints and bedding planes. Within the overburden it is controlled by the type and thickness of the deposits and the volume and size of the pore spaces between grains of silt, sand and gravel or stone fragments. In general, wells completed in the bedrock are suitable for domestic requirements only. The ground water availability in the overburden deposits ranges from poor to good. Locally, overburden aquifers are the most productive sources of ground water within the study area.

The most important aquifers within the overburden are the surficial sands and gravels in the Oak Ridges, the outwash deposit within the Till Plain and the deltaic sand belt within the Lake Iroquois Plain. Less important aquifers, although extensively tapped, are the silt and sand deposits associated with the Upper Glacial Till Unit and the bedrock channel deposits.

16. Available data indicate that the ground water divides coincide very closely with the topographic divides. Ground water flows away from these divides towards the stream valleys, with the general direction of flow being from the Oak Ridges towards Lake Ontario.

17. The mean ground water hydraulic gradient is 0.015 (dimensionless) compared to a mean topographic gradient of 0.017, which indicates that the water table within the study area follows the topography, at least on a broad scale.

18. Data on observation wells indicate that the ground water levels decline or rise in time, mainly as a result of the net effect of the ground water recharge and discharge processes. They reflect the quantity of water stored within the ground water domain. The observed ground water level fluctuations at different observation wells in the study area, for the period 1968-1973, varied between 0.3 and 3.5 m and averaged 1.8 m. On a seasonal basis, the ground water level fluctuations could be described as having a two-peak-two-recession pattern, which is remarkably similar to the seasonal runoff variation process. The two peaks occur during the spring and the fall, the first being high and the second moderate. The two recessions occur during the winter and the summer, the first being short lived and the second steeper initially and longer lived.

19. Estimates of the transmissivity values for the overburden and the upper 15 m of the bedrock range from 1.1 to 313.1 m^2/day with an average value of 26.8 m^2/day.

20. A hydrologic method, which is based on the equation of continuity, was used to arrive at estimates of the mean storage coefficient values for all sub-basins in the Wilmot Creek watershed. Four values were computed as the mean storage coefficients for sub-basins W-1, W-2, W-3 and local area (LA). These values are: 0.060, 0.037, 0.003 and 0.011, respectively.

21. Ground water discharge in the study area occurs mainly in the valleys of the Bowmanville, Soper and Wilmot creeks and their major tributaries. The amounts of ground water discharge from various basins and sub-basins in the study area were estimated by separating the streamflows at respective gauging stations into a surface runoff component and a baseflow component. The results obtained from baseflow analyses indicate the following:

   i baseflow decreases slightly during the winter months (January-February); increases substantially during the spring months (March-May); decreases continually during the summer and early fall months (June-October) and recovers during late fall and early winter months (November-December). This pattern is analogous to the patterns of ground water level and surface runoff variation processes.

   ii The ratios of annual baseflow to total annual runoff for various sub-basins in the study area, vary from 92.0 percent at station W-1 to 27.1 percent at station W-3.

   iii The ratios of annual baseflow to annual precipitation vary from 38.8 percent in sub-basin W-1 to 9.4 percent in sub-basin W-3.

   iv The long term means of annual baseflow from different sub-basins range from 83.7 to 330.6 mm.

22. Recharge is the process by which ground water is replenished and it involves the vertical leakage of water through the soil and sub-soil deposits to the saturated zone. The major sources of recharge in the study area are rain and snowmelt. Recharge is irregularly distributed in time and space.

Two methods were employed to arrive at estimates of monthly and annual ground water recharge amounts for various basins and sub-basins in the study area. The first method is hydrogeological and the second is hydrometeorological.

A comparison between the results of both methods indicates the following:

i Estimates of the annual ground water recharge by both methods are, with a few exceptions, very close.

ii Both methods show that most of the recharge occurs during the spring and late fall months (March, April, May, November and December); less recharge occurs during the January and February months, and little or no recharge occurs during the period June-October.

   According to the hydrogeological method, the recharge amounts during the months of March and April are of the same magnitude, most of the time whereas, the recharge in April is much higher than that in March, according to the hydrometeorological method.

   Some recharge occurs nearly every month during the period June-October, according to the hydrogeological method, whereas no recharge is indicated by the hydrometeorological method.

iii The annual ground water recharge within the Oak Ridges physiographic unit is in the range of 275-375 mm; within the Till Plain physiographic unit, it is in the range of 150-200 mm; and within the Lake Iroquois Plain physiographic unit, it is in the range of 50-100 mm. 10.8 – 14.7 in

23. Simulation of ground water flow by mathematical models is a process which duplicates the essence of the physical ground water flow system.

A composite two-dimensional mathematical model based on the Illinois aquifer simulation program (Prickett and Lonnquist, 1971) was applied to simulate the steady and unsteady flow of ground water in the Wilmot Creek basin. The model uses a modified, iterative, alternating direction, implicit method to solve the resulting set of finite difference equations describing the ground water flow.

A comparison between the simulated and measured ground water levels for the steady state case indicates that the general pattern of ground water level distribution throughout the basin was successfully generated within $\pm$ 8 m.

The water table elevations throughout the Wilmot Creek basin were computed for the unsteady flow case at the end of each month of the simulation period 1967-1972. These elevations were compared with field data on observation wells to calibrate and verify the model. Calibration proceeded with the assumption that the initial transmissivity distribution derived from pumping test information throughout the basin was reasonable.

The following points summarize the findings:

i The agreement between observed and computed water levels improved with increasing time in the simulation period. The observed ground water level fluctuations during the study period varied from 0.35 to 3.53 m and averaged 1.81 m. The difference between observed and computed levels at the end of the five year simulation period was within 0.30 m for 16 of the 25 observation wells.

ii A significant discrepancy of up to 8 m between the observed and initial computed levels was encountered at eight observation wells; whereas, a lesser discrepancy of up to 3 m was encountered at the other observation wells.

iii The assignment of an average storage coefficient value for each sub-basin proved to be the major source of error. It was found that a change of up to 50 percent in the value of the storage coefficient at most of the observation wells was needed to significantly improve the computed water level elevations.

iv The estimated recharge rates were reasonable most of the time, with the exception of certain summer months, where these rates were somewhat underestimated.

v A comparison between simulated annual ground water discharge and estimated annual baseflow by streamflow separation for station 02HD009, indicates that they are in close agreement. However, the simulated monthly ground water discharges show less variations than the estimated monthly baseflows.

24. The investigations of the hydrologic processes within various sub-basins in the study area indicate that there are wide variations in the characteristics of different sub-basins. Because of these wide variations between sub-basins, it is possible to conclude that one cannot consider one of these sub-basins as a 'representative' basin from which these characteristics can be transferred more or less directly to other basins. Nor are the hydrologic and hydrogeologic phenomena exactly alike in two sub-basins, or even exactly alike at different times in one sub-basin. The characteristics of individual sub-basins differ considerably, particularly if the size of these sub-basins is small or if small time increments of the investigated hydrologic process are considered.

Only when the broad hydrologic and hydrogeologic characteristics of different regimes are considered, does it become possible to identify general patterns and similarities between basins. These general patterns and similarities could then be ascribed to larger physiographic and climatic environments which contain these basins. Accordingly, it is appropriate to define a representative basin as one that has been chosen and instrumented to represent the broad hydrologic and hydrogeologic characteristics of one or more larger physiographic and climatic environments. Within the framework of this definition, it is possible to conclude that the study area represents three distinct physiographic and climatic environments in Southern Ontario. These environments are: the Oak Ridges interlobate moraine, the Till Plain (South Slope) and the Lake Iroquois Plain. The general characteristics of these environments are given in Table 35.

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Table 1. Monthly, Annual and 5-Year Mean Temperatures as Measured at Leskard, McLaughlin, Mostert and Orono Meterological Stations for the Period 1969-1973.

(All values in °C)

Station	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Leskard	1969	-7.0	-4.9	-3.1	6.3	10.8	15.6	19.1	19.5	14.6	7.7	2.6	-6.9	6.2
	1970	-6.4	-8.2	-3.0	6.2	11.6	16.7	19.9	19.2	14.8	10.1	3.8	-6.9	6.5
	1971	10.4	-6.0	-3.9	3.1	11.3	17.1	18.1	17.9	16.2	12.1	1.3	-2.8	6.2
	1972	-7.0	-8.5	-4.4	2.6	12.9	15.7	19.7	17.9	14.9	5.5	0.8	-4.1	5.5
	1973	-5.4	-7.5	3.0	5.8	10.6	17.7	20.0	20.8	14.5	10.2	2.6	-4.9	7.3
	Means	-7.2	-7.0	-2.3	4.8	11.4	16.6	19.3	19.1	15.0	9.1	2.2	-5.1	6.3
McLaughlin	1969	-7.0*	-6.6	-4.0	5.9	10.9	15.3	19.3	20.1	15.2	7.9	2.0	-7.3	6.0
	1970	-11.6	-8.6	-4.0	5.8	11.8	16.4	19.8	19.1	14.8	9.9	3.1	-7.2	5.8
	1971	-10.8	-6.5	-4.6	3.1	11.2	17.4	18.2	17.9	16.4	12.2	1.1	-3.3	6.1
	1972	-7.3	-9.0	-5.7	1.7	13.1	15.2	19.4	17.7	14.8	5.4	0.2	-4.8	5.1
	1973	-6.3	-8.7	2.3	5.3	10.2	17.8	20.2	21.1	15.1	10.3	1.7	-5.6	6.9
	Means	-8.5	-7.9	-3.2	4.3	11.4	16.4	19.4	19.2	15.3	9.2	1.6	-5.7	5.9
Mostert	1969	-5.8	-3.8	-1.8	6.4	10.2	15.8*	19.3	19.3	14.7	8.1	3.7	-5.8	6.7
	1970	-11.2	-3.6	-1.9	6.2	11.1	16.6	19.7	18.9	15.1	10.3	4.7	-5.9	6.5
	1971	-9.1	-4.7	-3.1	4.8	11.1	16.3	18.8	17.4	16.6	14.2	2.5	-1.7	6.8
	1972	-5.5	-7.5	-3.7	2.8	12.1	15.3	18.8	17.6	15.2	6.3	1.9	-3.1	5.9
	1973	-4.4	-6.9	3.7	6.3	10.7	17.8	20.1	20.9	14.9	10.1	3.6	-3.8	7.7
	Means	-7.2	-5.4	-1.3	5.3	11.0	16.4	19.3	18.8	15.3	9.7	3.3	-4.1	6.7
Orono	1969	-6.4	-4.5	-2.5	6.9	11.2	15.8	19.9	20.3	15.1	8.2	3.4	-6.1	6.8
	1970	-10.9	-7.7	-2.6	6.8	11.9	16.7	20.2	19.9	15.2	10.1	3.8	-6.6	6.4
	1971	-9.3	-5.2	-3.7	4.0	10.8	16.6	18.4	17.7	16.3	12.2	0.7	-2.4	6.3
	1972	-6.4	-8.2	-4.1	2.8	12.6	15.3	19.3	17.9	15.2	5.6	0.6	-3.8	5.6
	1973	-5.4	-7.8	3.2	5.8	10.6	17.9	20.3	21.4	14.9	9.9	2.9	-4.8	7.4
	Means	-7.6	-6.7	-1.9	5.3	11.4	16.5	19.7	19.4	15.3	9.2	2.3	-4.7	6.5

* Estimate

Table 2. Normal, Maximum and Minimum Temperature as Recorded at Orono Station

(All values in °C)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year Mean
Mean daily temperature	-6.9	-6.1	-1.3	6.0	11.7	17.4	20.0	19.3	15.1	9.3	2.9	-4.0	6.9
Mean daily maximum temperature	-2.3	-1.3	3.3	11.4	17.7	23.6	26.2	25.4	20.9	14.8	6.9	0.1	12.2
Mean daily minimum temperature	-11.6	-10.9	-0.4	0.6	5.7	11.3	13.8	13.2	9.3	3.8	-1.2	-8.2	1.7
Extreme maximum temperature	12.8	15	22.2	28.9	32.2	35.0	39.4	36.1	34.4	27.2	22.8	16.1	39.4
Extreme minimum temperature	-32.2	-34.4	-28.3	-17.2	-6.1	0.0	2.8	0.0	-5.0	-12.8	-21.1	-32.2	-34.4

Table 4. Normal Monthly, Annual and Maximum 24-Hour Rainfall, Snowfall and Total Precipitation as Recorded at Orono Station

(All values in mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean rainfall	26	28	42	64	80	65	82	67	66	72	67	45	704
Mean snowfall	445	414	259	71	2	0	0	0	0	10	114	323	1638
Mean total precipitation	70	69	68	71	80	65	82	67	66	73	78	77	869
Greatest rainfall in 24 hours	50	44	55	48	72	60	63	67	62	66	52	44	72
Greatest snowfall in 24 hours	279	272	259	165	61	0	0	0	T	114	419	356	419
Greatest precipitation in 24 hours	50	44	55	48	72	60	63	67	62	66	52	44	72

T - trace

Table 5. Stratigraphic Column of the Bedrock in the Study Area Based on Stratigraphic Nomenclature by Liberty (1969)

Era	Period	Epoch	Group	Formation	Member
Paleozoic	Ordovician	Upper	Nottawassaga	Whitby	Middle
					Lower
		Middle	Simcoe	Lindsay	
				Verulam	Upper
					Lower
				Bobcaygeon	Upper
					Middle
					Lower
				Gull River	Upper
					Middle
					Lower
			Basal	Shadow Lake	
Precambrian					

Table 7. Analysis of Till Samples Collected from the Bluffs Along the Shoreline of Lake Ontario (Bowmanville-Newcastle area)

Sample no.	Mechanical Analysis			Carbonate Analysis			Material
	Sand %	Silt %	Clay %	Calcite %	Dolomite %	Calcite/Dolomite	
8	21.0	44.0	35.0	9.0	4.0	2.5	Lower Till
17	19.0	58.0	23.0	7.0	8.0	0.9	Lower Till
19	21.5	44.0	34.5	22.2	9.4	2.4	Lower Till
73	20.0	42.0	38.0	8.2	3.8	2.2	Lower Till
83	13.0	54.5	32.5	26.0	6.8	3.9	Lower Till
94	6.0	60.0	34.0	35.4	8.8	4.0	Lower Till
95	15.0	49.0	36.0	-	-	-	Lower Till
96	12.0	65.0	23.0	27.0	9.2	2.9	Lower Till
97	24.0	48.0	28.0	34.0	7.8	4.4	Lower Till
12	13.3	47.7	39.0	34.0	4.0	8.5	Middle Till
13	11.7	41.9	46.4	39.0	7.0	5.5	Middle Till
14	13.0	69.0	18.0	28.0	6.8	4.1	Middle Till
21	17.0	57.0	26.0	34.2	8.4	4.1	Middle Till
2	46.0	41.5	12.5	38.0	4.0	9.5	Upper Till
3	42.0	40.0	18.0	41.0	5.0	8.2	Upper Till
4	49.6	36.7	13.7	49.0	5.0	9.8	Upper Till
5	41.7	35.1	23.2	42.0	5.0	8.4	Upper Till
9	60.3	32.6	7.1	40.0	6.0	6.7	Upper Till
11	49.0	45.4	5.6	35.0	7.0	5.0	Upper Till
25	45.0	40.7	14.2	34.8	6.8	5.1	Upper Till
26	45.0	42.7	12.3	38.8	7.0	5.5	Upper Till
29	54.8	33.2	12.0	36.8	6.8	5.4	Upper Till
31	50.0	38.0	12.0	40.4	6.8	5.9	Upper Till
35	55.0	34.0	10.5	36.0	7.2	5.0	Upper Till
37	42.0	41.0	17.0	49.6	6.4	7.8	Upper Till

Table 7 (cont'd)

Sample no.	Mechanical Analysis			Carbonate Analysis			Material
	Sand %	Silt %	Clay %	Calcite %	Dolomite %	Calcite/Dolomite	
39	59.0	29.0	12.0	38.6	6.8	5.7	Upper Till
52	53.0	42.2	4.8	37.0	6.8	5.4	Upper Till
33	60.0	30.0	10.0	37.6	7.2	5.2	Upper Till
36	44.0	36.0	20.0	41.2	6.0	6.9	Upper Till
42	45.0	39.0	16.0	38.6	6.8	5.7	Upper Till
43	43.0	49.0	8.0	34.0	8.2	4.1	Upper Till
44	43.0	39.5	17.5	38.6	7.0	5.5	Upper Till
45	49.0	37.5	13.5	37.3	7.7	4.8	Upper Till
46	49.0	36.5	14.5	34.8	6.2	5.6	Upper Till
50	47.5	44.5	8.0	35.2	6.0	5.9	Upper Till
51	62.0	27.0	11.0	40.4	6.8	5.9	Upper Till
57	46.5	40.5	13.0	37.8	7.0	5.4	Upper Till
58	50.2	40.0	9.7	32.2	6.2	5.2	Upper Till
60	52.7	31.5	15.7	34.4	7.6	4.5	Upper Till
66	43.0	47.5	9.5	35.2	6.0	5.9	Upper Till
76	55.0	32.0	13.0	36.0	7.4	4.9	Upper Till
81	57.0	37.0	6.0	36.0	8.2	4.4	Upper Till
82	-	-	-	35.4	8.8	4.0	Upper Till
62	57.2	27.8	14.0	38.2	7.0	5.5	Upper Till
64	53.0	41.0	6.0	39.0	5.2	7.5	Upper Till
80	52.0	36.0	12.0	36.0	4.8	7.2	Upper Till

Table 8. Monthly Variations of Various Components of the Hydrologic Cycle, Including the Resulting Ground Water Recharge, Storage Change and Discharge in Sub-basin W-2 during the Water-Year 1969-1970.

Hydrologic Process	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Annual
Mean temperature (Leskard, °C)	7.7	2.6	-6.9	-6.4	-8.2	-3.0	6.2	11.6	16.7	19.9	19.2	14.8	6.1
Rainfall (Leskard, mm)	59.2	89.2	40.1	8.1	11.2	67.8	63.0	59.9	48.5	54.9	34.5	60.7	597.1
Snowfall (Leskard, mm water eq.)	0.0	19.8	38.6	65.0	54.9	16.8	7.1	0.0	0.0	0.0	0.0	0.0	202.2
Total Precipitation (Leskard, mm)	59.2	109.0	78.7	73.2	66.0	84.6	70.1	59.9	48.5	54.9	34.5	60.7	799.3
Snow storage at beginning of month (Leskard, mm, water eq.)	0.0	0.0	18.3	52.3	109.2	158.0	113.8	0.0	0.0	0.0	0.0	0.0	
Snow storage at end of month (Leskard, mm, water eq.)	0.0	18.3	52.3	109.0	158.0	113.8	0.0	0.0	0.0	0.0	0.0	0.0	
Snowmelt during month (Leskard, mm)	0.0	1.5	4.3	8.4	5.6	61.0	120.9	0.0	0.0	0.0	0.0	0.0	
Rain and snowmelt during month (Leskard, mm)	59.2	90.6	44.5	16.5	16.8	128.8	183.9	59.9	48.5	54.9	34.5	60.7	799.3
Potential evapotranspiration (Thornthwaite method, mm)	37.6	12.9	0.0	0.0	0.0	0.0	34.9	70.4	102.1	128.3	117.3	76.2	579.3
Actual evapotranspiration (based on an assumed soil moisture storage of 100 mm),mm	37.6	12.9	0.0	0.0	0.0	0.0	34.9	70.4	85.6	64.5	44.7	62.5	414.0
Surface runoff (Station W-2,mm)	30.1	35.9	35.7	27.3	22.6	33.5	50.2	33.5	25.0	28.6	24.5	25.9	372.8
Ground water discharge from baseflow seperation (W-2, mm)	20.5	32.0	33.6	25.5	20.9	26.2	34.5	31.1	23.4	23.0	22.2	20.9	318.8
Ground water recharge (mm)	0.0	58.1	42.2	14.7	15.1	121.5	133.3	0.0	0.0	0.0	0.0	0.0	385.1
Change in ground water storage (mm)	-20.5	+26.1	+8.8	-10.8	-5.8	+95.3	+98.8	-31.1	-23.4	-23.0	-22.2	-20.9	+71.3
Change in soil moisture (mm)	+12.0	+15.7	0.0	0.0	0.0	0.0	0.0	-12.9	-39.1	-15.2	-12.5	-6.8	-58.8

Rain and Snowmelt = Runoff + Actual Evaporation $\pm$ Change in Ground Water Storage $\pm$ Change in Soil Moisture Storage

799.3 mm = 372.8 mm + 414.0 mm $\mp$ 71.3 mm $\mp$ 58.8 mm

Table 9. Areal Distribution of Precipitation Stations for the Thiessen Network by Basin and Sub-basin in the Study Area. (All values in km^2)

Precipitation Stations	Bowmanville Creek above HD6					Soper Creek above HD7					Wilmot Creek above HD9				Bowmanville, Soper and Wilmot Drainage Basin
	B-1	B-2*	B-3	B-4	HD6	S-1	S-2	S-3*	S-4	HD7	W-1	W-2*	W-3	HD9	
McLaughlin	6.27	20.46		12.74	36.15										36.15
Mostert					0.26				7.25	18.38				1.29	19.93
Tyrone			8.94	11.91	28.54		9.58	1.04		10.62					39.16
Hampton			1.45	1.40	20.07		0.77			3.23					23.30
Bowm. STP					1.48					2.59					4.07
Leskard						4.68	1.67	9.00		10.67	10.80	27.11		33.20	43.87
Happy Valley							3.78	6.99	3.11	26.15				6.46	32.62
Orono									3.57	3.57			1.89	15.88	19.45
Clarke													19.01	25.74	25.74
Total	6.27	20.46	10.39	26.05	86.50	4.68	15.80	17.03	13.93	75.20	10.80	27.11	20.89	82.58	244.28

* Sub-basin B-2 includes sub-basin B-1; sub-basin S-3 includes sub-basin S-1, and sub-basin W-2 includes sub-basin W-1.

Table 10. Weights of Precipitation Stations for the Thiessen Network by Basin and Sub-basin in the Study Area. (All values are dimensionless)

Precipitation Stations	Bowmanville Creek above HD6					Soper Creek above HD7				Wilmot Creek above HD9					Bowmanville, Soper and Wilmot Drainage Basin
	B-1	B-2	B-3	B-4	HD6	S-1	S-2	S-3	S-4	HD7	W-1	W-2	W-3	HD9	
McLaughlin	1.000	1.000		0.489	0.418										0.148
Mostert					0.003				0.520	0.244				0.016	0.081
Tyrone			0.860	0.457	0.330		0.606	0.061		0.141					0.160
Hampton			0.140	0.054	0.232		0.049			0.043					0.095
Bowm. STP					0.017					0.034					0.017
Leskard						1.000	0.106	0.529		0.142	1.000	1.000		0.402	0.180
Happy Valley							0.239	0.410	0.223	0.348				0.078	0.134
Orono									0.257	0.048			0.090	0.192	0.080
Clarke													0.910	0.312	0.105

Table 11. Monthly and Annual Total Precipitation and 6-Year Means as Measured at Various Precipitation Stations in the Study Area for the Period 1968-1973.
(All values in mm)

Station	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
Bowmanville STP	1968	78.7	32.8	49.5	22.1	93.5	68.1	19.8*	75.4	59.7	55.4	86.6	61.0	702.6*
	1969	57.9	7.4*	36.1	83.6	88.6e	70.6	93.5	86.1	24.1	65.5	97.5	49.5	760.5*
	1970	54.9	31.0	60.5	70.8	54.4	69.3	67.8	23.1*	40.9	124.5	51.6	106.9	755.6
	1971	50.8	83.1	46.2	29.2*	33.0	104.6	58.9	118.1	42.7	60.7	54.9	86.6	768.9
	1972	50.5	45.2*	89.2	88.1	53.1	70.1	84.8	106.4	66.0	72.6	59.9	68.1	854.2
	1973	59.9	35.3*	102.4	65.8	101.1	56.6	38.6	59.7	40.9	88.9	74.9	69.3	793.5
	Means	58.8	39.1*	64.0	59.9	70.6	73.2	60.6	78.1	45.7	77.9	70.9	73.6	772.6
Clarke	1968	52.3	36.6	42.2	26.2	79.0	55.4	12.4*	65.3	53.8	53.3	91.9	66.0	635.0*
	1969	51.1	10.2*	34.0	94.5	87.4	66.0	132.1	94.7	10.7	84.1	98.3	62.2	825.2
	1970	56.6	41.9	67.3	77.2	75.2	70.9	85.9	33.3*	43.7	116.3	58.2	66.5	793.0
	1971	55.9	69.8	31.7	26.9*	32.8	105.9	75.7	61.2	48.3	59.2	60.5	88.4	720.9
	1972	60.5	80.3	64.0	52.6	43.7*	81.8	99.8	120.6	76.7	76.5	58.7	110.0	925.1
	1973	35.8	44.2	94.7	74.7	96.3	81.0	30.0*	37.8	46.0	95.2	81.0	65.0	781.8
	Means	52.0	47.2	55.6	58.7	69.1	76.8	72.6	68.8	46.5*	80.8	74.8	76.4	779.8
Hampton	1968	52.6	40.6	60.2	29.7	115.8	64.3	19.8*	83.3	88.6	59.7	121.9	62.0	798.6
	1969	51.6	10.2	39.1	95.2	88.6	62.7	104.1	82.0	8.9*	77.2	90.7	63.5	748.5*
	1970	52.8	27.4*	86.1	80.3	53.6	57.1	84.6e	38.6	84.6	112.8	65.8	107.2	850.9
	1971	48.0	57.1	48.3	35.1	28.4*	129.8	83.8	76.7	74.2	55.6	71.9	120.4	829.3
	1972	39.1*	57.4	57.9	120.6	57.6	71.9	67.6	124.7	75.7	80.0	62.7	157.7	973.1
	1973	58.7	50.3	121.2	86.6	102.1	50.3	31.0*	31.0	39.9	104.9	83.0	89.1	848.1
	Means	50.5	40.5*	68.8	74.6	74.3	72.7	65.2	72.7	62.0	81.7	82.7	100.0	841.4
Happy Valley	1968	75.4	44.4	54.6	26.7	102.6	62.5	16.5*	69.6	78.2	57.7	106.2	66.0	760.5
	1969	53.6	15.0	39.9	88.4	86.6	74.9	87.4	111.3	7.4*	65.0	111.3	56.4	797.1
	1970	48.0	33.0	66.3	75.9	61.0	50.5	89.7	32.8*	42.4	119.1	66.0	74.2	759.0*
	1971	44.2	101.6	43.9	35.3	29.5*	126.2	77.0	67.3	56.1	59.4	57.7	70.6	768.9
	1972	44.2*	87.6	116.6	75.7	48.0	79.5	97.8	108.5	75.7	81.0	80.3	120.1	1015.0
	1973	45.7	45.7	120.4	67.8	89.9	60.7	33.0*	64.8	43.7	101.1	86.1	41.1	800.1
	Means	51.8	54.6	73.6	61.6	69.5	75.7	66.9	75.7	50.6*	80.5	84.6	71.4	816.8

Table 11 (cont'd.)

Station	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
Leskard	1968	70.1	70.9	66.5	29.2	106.9	56.9	12.2*	94.2	82.6	60.4	126.5	111.0	887.5
	1969	65.0	32.0	38.1	97.0	87.9	74.2	119.4	117.6	8.6*	59.2	109.0	78.7	886.7
	1970	73.2	66.0	84.6	70.1	59.9	48.5	54.9	34.5*	60.7	98.8	75.9	78.2	805.4*
	1971	85.6	123.4	59.9	37.6	33.8*	94.0	88.1	54.1	52.3	47.2	77.2	115.1	870.7
	1972	62.2	109.7	87.9	69.3	55.1*	97.0	83.6	115.8	77.0	89.2	70.6	146.8	1064.3
	1973	30.7*	45.5	117.1	91.7	94.2	68.8	40.1	71.6	42.2	112.3	101.6	94.7	910.6
	Means	64.5	74.6	75.7	65.8	73.0	73.2	66.4	81.3	53.9*	77.9	93.5	104.1	904.2
McLaughlin	1968	81.0e	62.7e	79.8e	30.7e	100.1e	100.1	40.4	110.7	108.5	53.1	143.5	80.8	991.4
	1969	77.0	20.3	34.3	95.5	95.8	65.5	116.1	59.9	7.4*	52.3	120.4	26.9	771.4
	1970	54.9	68.3	46.0*	81.5	48.3	46.0	88.1	52.6	88.1	94.7	74.9	50.8	794.2
	1971	46.0	52.8	32.0	36.1	31.0*	154.9	97.8	58.7	65.5	38.1	55.4	101.9	770.1*
	1972	46.7	74.2	56.4	42.9*	56.6	102.4	52.3	110.0	71.9	93.5	61.2	106.4	876.6
	1973	32.5	31.0*	117.6	76.5	110.7	67.3	57.1	56.4	47.7	120.1	105.2	64.3	886.5
	Means	56.4	51.6*	61.0	60.5	73.8	89.4	75.3	74.7	64.8	75.3	93.4	71.8	848.4
Mostert	1968	70.1	33.8	54.1	24.9	94.0	61.7	9.7*	75.2	61.2	55.4	114.8	89.9	744.7
	1969	63.2	12.4*	31.7	89.7	83.6	67.1e	108.7	102.1	20.3	64.0	97.0	58.4	798.3
	1970	37.1	29.7*	52.3	66.8	66.5	68.1	75.7	30.2	41.6	131.1	52.1	61.2	712.5*
	1971	31.2	80.0	27.2*	29.7	33.3	108.7	63.8	102.1	45.2	65.3	54.8	101.6	742.3
	1972	21.6*	57.4	81.5	67.8	53.8	80.0	81.5	110.2	64.0	78.2	75.7	113.0	884.9
	1973	35.3	33.8*	107.2	69.6	95.8	56.9	36.6	51.8	43.7	103.1	79.0	61.5	774.2
	Means	43.1	41.2*	59.0	58.1	71.2	73.7	62.7	78.6	46.0	82.8	78.9	80.9	776.2
Orono	1968	73.2	54.9	57.9	26.4	100.8	53.7	9.7*	66.0	59.7	53.1	121.7	87.9	765.6
	1969	64.8	20.8	30.2	88.6	84.6	59.4	109.2	56.9	8.9*	67.6	89.9	61.5	744.7*
	1970	65.3	63.2	64.8	60.5	84.8	70.9	114.8	36.3*	40.6	117.3	63.8	90.4	873.0
	1971	58.4	115.3	29.2	28.7	25.4*	115.6	60.2	73.9	42.7	55.4	66.3	90.7	761.7
	1972	44.4*	77.5	90.2	75.7	55.1	79.2	101.3	115.8	75.9	73.9	68.1	135.4	992.6
	1973	41.9	33.0	84.8	90.2	99.1	75.2	28.7*	43.7	46.0	80.5	101.1	48.5	772.7
	Means	58.0	60.8	59.5	74.0	75.0	75.7	70.6	65.4	45.6*	74.6	85.1	85.7	818.4

Table 11 (cont'd.)

Station	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
Tyrone	1968	61.0	46.2	61.0	25.9*	108.7	61.2	26.4	91.2	87.6	56.4	113.3	82.8	821.7
	1969	72.6	18.3	38.1	91.7	88.1	63.2	112.5	88.1	11.2*	66.8e	94.7	59.4	804.9
	1970	51.8	32.0*	72.4	77.2	65.0	38.1	99.6	32.5	74.4	101.6	68.8	77.7	791.2*
	1971	73.9	111.0	82.3	32.3	30.2*	133.1	88.1	58.4	67.3	46.5	60.2	111.0	894.3
	1972	59.2	96.8	124.0	69.6	50.8*	85.3	96.0	122.2	89.2	101.1	72.6	116.3	1083.1
	1973	41.4	40.6*	117.9	99.1	125.5	70.1	40.6	87.9	53.6	116.6	112.3	80.5	986.0
	Means	60.0	57.5*	82.6	66.0	78.0	75.2	77.2	80.0	63.9	81.5	87.0	87.9	896.9

* Minimum

__ Maximum

e Estimate

Table 12. Monthly and Annual Total Precipitation and 6-Year Means as Computed using the Arithmetic Mean and the Thiessen Polygon Methods for the Bowmanville, Soper and Wilmot Creeks Drainage Basin (1968-1973) (All values in mm)

Method	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total Annual
	1968	68.3	47.0	58.4	27.9	100.1	65.0	18.5	81.3	75.4	56.1	113.3	78.5	790.0
Arithmetic	1969	62.0	16.3	36.6	91.7	87.9	68.2	109.2	94.1	11.9	66.8	102.1	63.0	809.8
Mean	1970	54.9	43.7	66.8	73.4	63.2	57.7	84.6	34.8	57.4	113.0	64.0	78.7	792.2
Method	1971	54.9	88.1	45.0	32.0	30.7	119.1	77.0	74.4	54.9	54.1	62.0	98.6	790.7
	1972	47.5	76.2	85.3	73.7	52.8	83.1	84.8	115.1	74.7	82.8	68.1	119.4	963.4
	1973	42.4	39.9	109.2	80.3	101.6	65.3	37.3	56.1	45.0	104.9	89.4	69.6	841.0
	Means	55.0	51.9	66.9	63.2	72.7	76.4	68.6	76.0	53.2	79.6	83.1	84.6	831.2
	1968	67.8	50.5	60.5	27.4	101.6	65.5	19.8	84.8	80.3	56.6	118.4	82.3	815.6
Thiessen	1969	63.2	18.8	36.3	93.5	88.6	69.1	111.5	98.8	9.9	65.3	104.4	65.8	825.2
Polygon	1970	58.2	46.2	68.3	74.7	62.5	53.6	84.3	36.3	61.5	109.0	67.3	74.4	796.3
Method	1971	58.4	91.4	51.6	37.8	31.2	121.7	81.5	66.8	57.1	51.3	63.5	100.8	808.2
	1972	49.5	83.1	87.4	70.1	52.8	86.9	84.1	115.8	76.5	86.6	68.6	124.5	985.8
	1973	39.6	40.6	112.3	82.6	102.9	66.8	38.6	59.9	46.7	107.9	93.7	71.4	863.1
	Means	56.1	55.1	69.4	63.5	73.3	77.2	70.0	77.0	55.3	79.5	86.0	86.5	849.0

Table 13. Monthly and Annual Total Precipitation and 6-Year Means as Computed from the Thiessen Polygon Nework for Various Basins and Sub-basins in the Study Area (1968-1973) (All values in mm)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
Bowmanville Cr. Basin (02HD006)	1968	67.8	51.3	68.1	28.4	106.4	78.7	30.2	97.0	96.0	55.9	127.2	77.0	884.2
	1969	69.3	16.8	36.6	94.0	91.7	68.5	111.5	96.1	9.4	63.2	104.4	67.4	826.1
	1970	53.1	46.0	64.5	79.5	55.1	46.7	90.7	42.2	81.8	101.9	70.1	72.6	805.4
	1971	55.6	73.7	52.6	34.3	30.0	141.0	90.9	64.0	67.8	45.5	61.0	109.0	825.2
	1972	49.0	77.2	79.8	70.6	55.6	89.2	71.1	117.6	78.2	92.5	65.3	120.9	967.0
	1973	42.2	38.6	118.3	86.1	113.2	64.0	45.5	61.0	48.0	114.8	101.8	75.7	909.3
	Means	56.2	50.6	70.0	65.5	75.3	81.3	73.3	79.7	63.5	79.0	88.3	87.1	869.5
Soper Cr. Basin (02HD007)	1968	70.4	45.7	57.4	26.4	102.4	61.2	15.7	78.0	74.9	56.9	113.0	81.0	808.5
	1969	60.7	17.3	37.1	90.4	86.4	69.6	102.9	102.1	12.2	64.8	103.1	61.0	807.5
	1970	53.6	39.4	68.3	71.4	67.6	55.4	78.2	37.1	53.6	115.1	70.1	77.7	787.5
	1971	52.3	99.6	47.8	46.7	31.0	117.3	75.4	74.9	54.1	56.6	61.0	94.0	810.8
	1972	43.7	81.5	100.3	74.4	51.8	82.3	115.1	113.0	74.4	83.8	74.7	122.7	1017.8
	1973	41.4	41.4	114.0	78.0	98.6	62.5	35.6	63.0	45.0	105.4	89.4	63.0	837.2
	Means	53.6	54.1	70.9	64.5	72.9	74.7	70.6	78.0	52.3	80.5	85.3	83.3	840.7
Wilmot Cr. Basin (02HD009)	1968	65.5	54.4	56.1	46.0	96.5	56.4	11.9	77.5	68.3	56.6	113.3	88.6	791.2
	1969	59.7	21.3	35.3	94.0	86.9	68.6	118.9	112.5	9.4	69.1	101.9	68.1	845.6
	1970	64.0	54.9	73.4	70.9	69.6	60.5	79.2	34.5	65.3	110.0	66.5	76.2	825.0
	1971	67.1	102.6	53.1	33.3	31.2	104.4	77.7	62.0	49.3	53.8	67.8	98.6	800.9
	1972	56.1	92.2	83.1	65.8	51.1	87.1	93.2	116.6	76.2	81.5	67.1	130.3	1000.3
	1973	35.8	42.4	103.9	84.8	95.5	73.4	34.0	54.6	44.2	103.9	89.7	74.2	836.4
	Means	58.0	61.3	67.5	65.8	71.8	75.1	69.1	76.3	52.1	79.2	84.4	89.3	849.9
B-3	1968	59.7	45.5	60.7	26.4	109.7	61.5	25.4	90.2	87.9	56.9	114.6	79.8	818.1
	1969	69.6	17.3	38.4	92.2	88.1	63.2	111.3	87.1	21.1	68.3	95.8	59.9	812.3
	1970	51.8	31.2	74.2	77.5	63.5	40.9	97.5	31.0	75.9	103.1	68.3	78.2	793.2
	1971	70.1	103.6	77.5	32.5	30.2	132.8	87.4	61.0	68.3	47.8	62.0	112.3	885.4
	1972	56.4	91.4	114.8	77.0	51.8	83.6	91.9	122.7	87.4	98.0	71.4	111.8	1058.2
	1973	43.7	42.2	118.6	97.3	122.2	67.3	39.4	79.8	51.6	115.1	108.2	81.8	967.0
	Means	58.6	55.2	80.7	67.1	77.6	74.9	75.5	78.6	65.4	81.5	86.7	87.3	889.0

Table 13 (cont'd.)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
B-4	1968	70.4	54.1	70.4	28.4	105.2	80.5	33.0	100.3	98.0	54.9	128.5	80.8	904.5
	1969	73.7	18.8	36.3	93.7	91.9	69.3	113.5	98.3	8.9	60.2	109.0	68.4	842.1
	1970	53.3	49.8	60.2	79.5	56.1	43.2	93.2	42.7	81.8	98.8	71.6	64.5	794.8
	1971	58.9	79.8	55.9	34.3	30.5	143.5	92.7	59.4	66.8	42.9	58.4	107.2	830.3
	1972	51.8	83.6	87.4	59.4	54.4	93.0	73.2	117.1	79.8	96.3	66.5	113.8	976.1
	1973	38.1	36.6	117.9	87.1	117.1	67.8	48.3	69.6	50.0	117.3	107.2	73.2	930.4
	Means	57.7	53.8	71.4	63.7	75.9	83.0	75.7	81.2	64.2	78.5	90.2	84.6	879.7
S-2	1968	64.8	48.3	59.9	26.7	107.4	61.2	22.4	85.9	84.8	57.4	113.5	80.8	813.1
	1969	66.0	18.5	38.9	91.4	87.9	67.3	106.7	96.5	10.2	66.0	100.6	61.7	811.8
	1970	53.3	35.6	72.9	75.9	62.7	43.2	91.7	33.0	65.8	105.9	68.8	76.2	785.1
	1971	66.8	107.7	69.3	33.5	30.2	144.8	85.1	61.2	63.5	50.3	62.0	102.1	876.6
	1972	55.1	94.0	115.3	73.4	50.8	84.6	93.7	118.1	84.1	93.7	73.7	122.4	1058.9
	1973	42.2	42.9	118.4	90.2	112.5	66.8	38.4	78.0	67.1	111.8	103.4	73.2	944.6
	Means	58.0	57.8	79.1	65.2	75.2	78.0	73.0	78.8	62.6	80.8	87.0	86.1	881.7
S-3	1968	71.7	58.5	61.3	28.0	105.3	59.5	14.8	83.9	81.1	59.1	117.4	90.8	831.4
	196(	60.8	24.2	38.8	93.1	87.4	73.8	105.9	113.2	8.2	62.1	109.1	68.3	844.9
	1970	61.9	50.3	76.3	72.9	60.7	48.7	71.9	33.6	54.0	107.3	71.4	76.6	785.6
	1971	67.9	113.8	54.7	36.4	31.8	109.5	83.6	59.8	54.8	52.1	68.2	96.6	829.2
	1972	54.6	99.8	101.9	71.9	51.9	89.1	90.2	113.2	77.1	86.6	74.6	134.0	1044.9
	1973	37.4	45.3	118.5	82.3	94.4	65.6	37.2	69.9	43.5	107.9	95.8	71.8	869.6
	Means	59.1	65.3	75.3	64.1	71.9	74.4	67.3	78.9	53.1	79.2	89.4	89.7	867.6
S-4	1968	72.1	41.7	55.4	25.7	97.5	59.9	11.4	71.6	64.3	55.4	114.6	84.1	753.6
	1969	61.5	15.0	33.3	89.4	84.6	66.8	104.1	92.7	14.5	65.0	98.6	58.9	784.4
	1970	46.7	39.1	58.7	67.3	70.1	64.8	88.9	32.5	41.4	125.0	58.4	71.1	764.0
	1971	41.1	94.0	31.7	26.2	30.5	114.6	66.0	87.1	47.0	61.5	58.4	91.9	750.1
	1972	32.5	69.3	91.4	71.6	52.8	80.5	90.4	111.3	69.6	77.7	74.7	120.1	942.1
	1973	39.1	36.1	104.4	74.4	95.2	62.2	33.8	52.6	44.2	102.1	81.0	56.6	781.8
	Means	48.8	49.2	62.5	59.1	71.8	74.8	65.8	74.6	46.8	81.1	81.0	80.5	796.0

Table 13 (cont'd.)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total
W-3	1968	54.9	38.1	43.7	26.2	81.0	55.1	12.2	65.3	54.3	53.3	94.5	68.1	646.7
	1969	52.3	10.9	33.8	94.0	87.1	65.5	130.0	91.2	10.4	82.5	97.5	62.2	817.6
	1970	57.4	43.7	67.1	75.7	75.9	70.9	88.6	33.5	43.4	116.6	58.7	68.6	800.1
	1971	56.1	73.9	54.6	26.9	32.0	106.7	74.2	62.2	47.5	58.9	61.0	88.6	742.7
	1972	59.2	80.0	66.3	54.6	45.0	81.5	100.1	120.1	76.7	76.2	59.4	112.3	931.4
	1973	36.3	43.2	93.7	76.2	96.5	80.5	29.7	38.4	46.0	95.8	81.0	64.5	781.8
	Means	52.7	48.3	59.9	58.9	69.6	76.7	72.5	68.5	46.4	80.5	75.4	77.4	786.7

Table 14. Annual Total Precipitation, Snowfall in Terms of Millimeters of Water Equivalent and Their Ratios as Measured at Nine Precipitation Stations in the Study Area for the Period 1968-1973.

Station	1968			1969			1970			1971			1972			1973		
	P	S	S/P	P	S	S/P	P	S	S/P	P	S	S/P	P	S	S/P	P	S	S/P
Bowman. STP	702.6	116.8	0.17	760.5	71.9	0.09	755.6	162.6	0.21	768.9	133.6	0.17	854.2	126.2	0.15	793.5	70.1	0.09
Clarke	635.0	89.7	0.14	825.2	62.5	0.08	793.0	131.6	0.17	720.8	180.3	0.25	925.1	218.2	0.24	781.8	87.1	0.11
Hampton	798.6	107.7	0.13*	748.5	67.3	0.09	850.9	109.2	0.13	829.3	187.7	0.23	973.1	190.1	0.19	848.1	80.3	0.09
Happy Valley	760.5	149.3	0.19	797.0	111.8	0.14	758.9	119.4	0.16	768.9	243.1	0.32	1015.0	304.5	0.30	800.1	69.1	0.09
Leskard	887.5	261.9	0.29	886.7	123.7	0.14	805.4	206.0	0.26	870.7	276.3	0.32	1064.3	304.0	0.29	910.6	158.0	0.17
Mostert	744.7	121.4	0.16	798.3	48.8	0.06*	712.5	76.4	0.11*	742.9	108.2	0.15*	884.9	121.2	0.14*	774.2	52.3	0.07*
McLaughlin	991.4	?	?	881.4	87.1	0.10	794.3	181.4	0.23	770.1	178.3	0.23	876.5	203.2	0.23	886.5	90.4	0.10
Orono	765.6	192.3	0.25	744.7	84.8	0.11	873.0	176.0	0.20	761.7	187.2	0.25	992.6	217.9	0.22	772.7	54.1	0.07
Tyrone	821.7	132.3	0.16	804.9	87.9	0.11	791.2	120.4	0.15	894.3	232.9	0.26	1083.1	247.6	0.23	986.0	77.0	0.08

P = Total Annual Precipitation (mm)
S = Total Annual Snowfall (mm of water equivalent)
S/P = $\frac{\text{Annual Snowfall}}{\text{Annual Precipitation}}$
_ = Annual Maximum Ratio
* = Annual Minimum Ratio

Table 15. Precipitation, Snowfall in Terms of Millimeters of Water Equivalent and Their Ratios as Measured during the Winter Seasons (1967-1973) at Nine Precipitation Stations in the Study Area.

Station	1967-1968			1968-1969			1969-1970			1970-1971			1971-1972			1972-1973		
	PW	SW	SW/PW	PW	SW	SW/PW	PW	SW	SW/PW	PW	SW	SW/PW	PW	SW	SW/PW	PW	SW	SW/PW
Bowman. STP	337.3	132.6	0.39	341.5	69.8	0.20	364.2	117.6	0.32	363.8	198.2	0.54	414.4	158.2	0.38	406.1	57.2	0.14
Clarke	315.7	97.5	0.31	348.5	48.5	0.14	403.6	135.6	0.34	309.1	179.3	0.58	406.1	209.0	0.51	418.1	84.3	0.20
Hampton							405.2	165.5	0.41	404.9	244.6	0.60	467.3	220.4	0.47	537.2	93.3	0.17
Happy Valley	357.6	126.2	0.35	369.	102.1	0.28	390.9	145.3	0.37	365.3	218.7	0.59	452.4	244.1	0.54	480.1	172.5	0.36
Leskard	427.2	171.4	0.40	469.4	198.6	0.42	481.6	202.2	0.42	460.8	263.4	0.57	521.5	280.9	0.54	502.4	170.4	0.34
Mostert	317.2	98.3	0.31	401.8	51.3	0.13*	341.4	71.6	0.21	280.2	100.3	0.36	384.8	123.4	0.32	434.6	61.2	0.14
McLaughlin							398.0	186.4	0.47	292.6	170.9	0.58	375.2	198.1	0.53	425.2	94.7	0.22
Orono	381.5	153.2	0.40	414.0	132.6	0.32	405.1	154.7	0.38	385.8	188.5	0.49	444.8	203.2	0.46	453.4	96.0	0.21
Tyrone	358.4	124.5	0.35	416.8	81.5	0.19	387.6	122.9	0.32	446.0	222.2	0.50	520.7	244.6	0.47	487.9	90.2	0.18

PW = Precipitation during Winter Season (mm)
SW = Snowfall during Winter Season (mm water equivalent)
SW/PW = $\frac{\text{Snowfall in Winter}}{\text{Precipitation in Winter}}$

___ = Maximum Ratio
* = Minimum Ratio

Table 16. Monthly Rainfall (R), Snowfall (S), Precipitation (P), Snow Storage at Beginning of Month (SSBM), Snow Storage at End of Month (SSEM), Snowmelt During Month (SM) and Rain and Melt During Month (R + SM) as Measured and Computed at Various Precipitation Stations in the Study Area

(All values in mm)

Station		1967 - 1968							1968 - 1969						
		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
Bowmanville STP	R	64.5	63.7	0.0	24.9	29.5	22.1	204.7	69.1	40.1	46.2	2.5	30.2	83.6	271.7
	S	10.7	15.2	78.7	7.9	20.1	0.0	132.6	17.5	30.0	11.7	4.8	5.8	0.0	69.8
	P	75.2	79.0	78.7	32.8	49.5	22.1	337.3	86.6	70.1	57.9	7.4	36.1	83.6	341.5
	SSBM	0.0	0.5	8.4	66.0	36.8	0.0		0.0	0.0	29.0	0.0	0.0	5.8	
	SSEM	0.5	8.4	66.0	36.8	0.0.	0.0		0.0	29.0	0.0	0.0	5.8	0.0	
	SM	9.6	7.4	21.1	47.1	56.9	0.0		17.5	1.0	40.6	4.8	0.0	5.8	
	R+SM	74.2	71.1	21.1	62.0	86.4	22.1	337.3	86.6	41.1	86.9	7.4	30.2	89.4	341.5
		1969 - 1970							1970 - 1971						
	R	83.6	29.2	1.5	13.7	50.3	68.3	246.6	50.6	35.3	18.8	24.9	6.8	29.2	165.6
	S	14.0	20.3	53.3	17.3	10.2	2.5	117.6	1.0	71.6	32.0	54.2	39.4	0.0	198.2
	P	97.5	49.5	54.9	31.0	60.4	70.8	364.2	51.6	106.9	50.8	79.1	46.2	29.2	363.8
	SSBM	0.0	11.4	19.6	60.7	60.4	0.0		0.0	0.0	57.6	75.6	98.7	80.2	
	SSEM	11.4	19.6	60.7	60.4	0.0	0.0		0.0	57.6	75.6	98.7	80.2	0.0	
	SM	2.5	12.2	12.2	17.5	70.6	2.5		1.0	14.0	14.0	31.0	57.9	80.2	
	R+SM	86.1	41.4	13.7	31.2	120.9	70.8	364.2	51.6	49.3	32.8	55.9	64.8	109.4	363.8
		1971 - 1972							1972 - 1973						
	R	44.7	58.4	18.8	3.3	51.8	79.2	256.2	59.4	56.1	47.7	17.5	102.4	65.8	348.9
	S	10.2	28.2	31.7	41.9	37.3	8.9	158.2	0.5	26.7	12.2	17.8	0.0	0.0	57.2
	P	54.9	86.6	50.5	45.2	89.1	88.1	414.4	59.9	82.8	59.9	35.3	102.4	65.8	406.1
	SSBM	0.0	7.6	10.2	32.0	54.4	27.9		0.0	0.0	0.0	0.8	13.7	0.0	
	SSEM	7.6	10.2	32.0	54.4	27.9	0.0		0.0	0.0	0.8	13.7	0.0	0.0	
	SM	2.5	25.6	9.9	19.6	63.5	36.8		0.5	26.7	11.4	4.8	13.7	0.0	
	R+SM	47.2	84.1	28.7	22.9	115.3	116.3	414.4	59.9	82.8	59.2	22.3	116.1	65.8	406.1

Table 16 (cont'd)

Station		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
		1967 - 1968							1968 - 1969						
Clarke	R	72.4	55.1	12.7	22.9	29.0	26.2	218.2	90.4	44.4	38.4	0.0	31.5	95.2	300.0
	S	11.4	19.6	39.6	13.7	13.2	0.0	97.5	1.5	21.6	12.7	10.2	2.5	0.0	48.5
	P	83.8	74.7	52.3	36.6	42.2	26.2	315.7	91.9	66.0	51.0	10.2	34.0	95.2	348.5
	SSBM	0.0	0.0	16.5	39.1	17.0	0.0		0.0	0.0	21.6	0.0	0.0	2.5	
	SSEM	0.0	16.5	39.1	17.0	0.0	0.0		0.0	21.6	0.0	0.0	2.5	0.0	
	SM	11.4	3.0	17.0	35.8	30.2	0.0		1.5	0.0	34.3	10.2	0.0	2.5	
	R+SM	83.8	58.2	29.7	58.7	59.2	26.2	315.7	91.9	44.4	72.6	10.2	31.5	97.8	348.5
		1969 - 1970							1970 - 1971						
	R	88.1	35.3	1.3	20.3	50.8	72.1	268.0	56.9	29.7	4.8	12.7	0.0	25.6	129.8
	S	10.2	26.9	55.4	21.6	16.5	5.1	135.6	1.3	36.8	51.0	57.1	31.7	1.3	179.3
	P	98.3	62.2	56.6	41.9	67.3	77.2	403.6	58.2	66.5	55.9	69.8	31.7	26.9	309.1
	SSBM	0.0	10.2	28.2	66.3	77.7	12.7		0.0	0.0	27.2	75.2	122.4	99.6	
	SSEM	10.2	28.2	66.3	77.7	12.7	0.0		0.0	27.2	75.2	122.4	99.6	0.0	
	SM	0.0	8.9	17.3	10.2	81.5	17.8		1.3	9.6	3.0	54.6	100.8		
	R+SM	88.1	44.2	18.5	30.5	132.3	89.9	403.6	58.2	39.3	7.9	22.6	54.6	126.5	309.1
		1971 - 1972							1972 - 1973						
	R	43.7	66.0	6.6	2.5	31.7	46.5	197.1	51.0	69.3	27.7	21.8	89.7	74.2	333.8
	S	16.8	22.3	53.8	77.7	32.2	6.1	209.0	7.6	40.6	8.1	22.3	5.1	0.5	84.3
	P	60.4	88.4	60.4	80.3	64.0	52.6	406.1	58.7	110.0	35.8	44.2	94.7	74.7	418.1
	SSBM	0.0	9.4	10.2	28.7	98.0	91.9		0.0	0.0	0.2	5.1	24.4	0.0	0.0
	SSEM	9.4	10.2	28.7	98.0	91.9	0.0		0.0	0.2	5.1	24.4	0.0	0.0	
	SM	7.4	21.6	35.3	9.4	38.3	97.0		7.6	40.4	3.3	3.0	29.5	0.5	
	R+SM	51.0	87.6	41.9	11.9	70.1	143.5	406.1	58.7	109.7	31.0	24.9	119.1	74.7	418.1

Table 16 (cont'd)

Station		1967 - 1968 Nov	Dec	Jan	Feb	Mar	Apr	Total	1968 - 1969 Nov	Dec	Jan	Feb	Mar	Apr	Total
Hampton	R														
	S														
	P														
	SSBM														
	SSEM														
	SM														
	R+SM														
		1969 - 1970							1970 - 1971						
	R	80.0	44.4	0.0	0.0	35.0	80.3	239.7	65.3	16.8	5.3	27.7	10.2	35.0	106.3
	S	10.7	19.0	52.8	27.4	55.6	0.0	165.5	0.5	90.4	42.7	72.9	38.1	0.0	244.6
	P	90.7	63.5	52.8	27.4	90.7	80.3	405.2	65.8	107.2	48.0	100.6	48.3	35.0	404.9
	SSBM	0.0	10.7	29.7	76.4	95.5	117.9		0.0	0.0	87.4	130.0	189.0	196.1	
	SSEM	10.7	29.7	76.4	95.5	117.9	0.0		0.0	87.4	130.0	189.0	196.1	0.0	
	SM	0.0	0.0	6.1	8.4	33.3	113.8		0.5	3.0	0.0	14.0	31.0	196.1	
	R+SM	80.0	44.4	6.1	8.4	68.3	198.1	405.2	65.8	19.8	5.3	41.7	41.2	231.1	404.9
		1971 - 1972							1972 - 1973						
	R	37.8	81.0	2.5	0.0	14.0	111.5	246.8	58.2	103.1	41.9	33.0	121.2	86.6	444.0
	S	34.0	39.4	36.6	57.4	43.9	9.1	220.4	4.6	54.6	16.8	17.3	0.0	0.0	93.3
	P	71.9	120.4	39.1	57.4	57.9	120.6	467.3	62.7	157.7	58.7	50.3	121.2	86.6	537.2
	SSBM	0.0	9.1	35.3	71.9	129.3	153.2		0.0	0.0	39.4	13.2	17.5	0.0	
	SSEM	9.1	35.3	71.9	129.3	153.2	0.0		0.0	39.4	13.2	17.5	0.0	0.0	
	SM	24.9	13.2	0.0	0.0	20.1	162.3		4.6	15.2	42.9	12.9	17.5	0.0	
	R+SM	62.7	94.2	2.5	0.0	34.0	273.8	467.3	62.7	118.4	84.8	46.0	138.7	537.2	

Table 16 (cont'd)

Station		1967 - 1968							1968 - 1969						
		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
Happy Valley	R	75.9	47.0	12.7	30.0	39.1	26.7	231.4	79.8	35.8	31.7	0.0	31.2	88.4	266.9
	S	15.0	18.5	62.7	14.5	15.5	0.0	126.2	26.4	30.2	21.8	15.0	8.6	0.0	102.1
	P	90.9	65.5	75.4	44.4	54.6	26.7	357.6	106.2	66.0	53.6	15.0	39.9	88.4	369.1
	SSBM	0.0	1.3	12.2	57.9	36.1	0.0		0.0	1.3	30.2	0.0	4.1	8.4	
	SSEM	1.3	12.2	57.9	36.1	0.0	0.0		1.3	30.2	0.0	4.1	8.4	0.0	
	SM	13.7	6.9	17.0	36.3	51.6	0.0		25.1	1.3	52.1	10.9	4.3	8.4	
	R+SM	89.7	53.8	29.7	66.3	90.7	26.7	357.6	104.9	37.1	83.8	10.9	35.6	96.8	369.1
		1969 - 1970							1970 - 1971						
	R	99.3	2.0	8.4	14.5	50.0	71.4	245.6	64.5	35.3	2.8	0.0	8.6	35.3	146.5
	S	11.9	54.4	39.6	18.5	16.3	4.6	145.3	1.5	38.9	41.4	101.6	35.3	0.0	218.7
	P	111.3	56.4	48.0	33.0	66.3	75.9	390.9	66.0	74.2	44.2	101.6	43.9	35.3	365.2
	SSBM	0.0	11.9	57.7	87.9	96.0	30.2		0.0	0.0	29.2	67.6	159.3	139.9	
	SSEM	11.9	57.7	87.9	96.0	30.2	0.0		0.0	29.2	67.6	159.3	139.9	0.0	
	SM	0.0	8.6	9.6	10.2	82.0	34.8		1.5	9.6	3.0	9.9	54.6	139.9	
	R+SM	99.3	10.7	18.0	24.6	132.1	106.2	390.9	66.0	45.0	5.8	9.9	63.2	175.3	365.2
		1971 - 1972							1972 - 1973						
	R	23.9	39.6	13.2	3.6	63.0	65.0	208.3	62.0	13.2	34.8	18.3	111.5	67.8	307.6
	S	33.8	31.0	31.0	84.1	53.6	10.7	244.1	18.3	106.9	10.9	27.4	8.9	0.0	172.5
	P	57.7	70.6	44.2	87.6	116.6	75.7	452.4	80.3	120.1	45.7	45.7	120.4	67.8	480.1
	SSBM	0.0	19.0	17.0	24.6	100.1	123.7		0.0	1.3	84.1	13.2	39.4	0.0	
	SSEM	19.0	17.0	24.6	100.1	123.7	0.0		1.3	84.1	13.2	39.4	0.0	0.0	
	SM	14.7	33.0	35.0	8.6	38.6	125.7		17.0	39.9	64.5	3.0	48.3	0.0	
	R+SM	38.6	72.6	36.6	12.2	101.6	190.7	452.4	79.0	53.1	99.3	21.3	159.8	480.1	

Table 16 (cont'd)

Station		1967 - 1968							1968 - 1969						
		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
Leskard	R	93.2	54.6	14.5	28.9	35.6	29.2	255.8	84.4	19.1	35.1	1.5	33.3	97.0	270.8
	S	20.1	22.9	55.6	41.9	31.0	0.0	171.5	41.4	91.9	30.0	30.5	4.8	0.0	198.6
	P	113.3	77.2	70.1	70.9	66.5	29.2	427.2	126.5	111.0	65.0	32.0	38.1	97.0	469.4
	SSBM	0.0	0.2	17.3	63.0	81.8	0.0		0.0	0.2	56.9	17.8	38.6	3.6	
	SSEM	0.2	17.3	63.0	81.8	0.0	0.0		0.2	56.9	17.8	38.6	3.6	0.0	
	SM	19.8	5.8	9.9	23.1	112.8	0.0		41.1	30.7	73.4	9.6	39.9	3.6	
	R+SM	113.0	60.2	24.4	52.1	148.3	29.2	427.2	126.0	49.8	108.5	11.2	73.2	100.6	469.4
		1969 - 1970							1970 - 1971						
	R	89.1	40.1	8.1	11.2	67.8	63.0	279.4	74.7	17.3	6.6	52.1	12.7	34.0	197.4
	S	19.8	38.6	65.0	54.9	16.8	7.1	202.2	1.3	61.0	79.0	71.4	47.2	3.6	263.4
	P	109.0	78.7	73.2	66.0	84.6	70.1	481.6	75.9	78.2	85.6	123.4	59.9	37.6	460.8
	SSBM	0.0	18.3	52.3	109.0	158.0	113.8		0.0	0.0	56.4	133.9	179.8	199.1	
	SSEM	18.3	52.3	109.0	158.0	113.8	0.0		0.0	56.4	133.9	179.8	199.1	0.0	
	SM	1.5	4.3	8.4	5.6	61.0	120.9		1.3	4.6	1.5	25.6	27.9	202.7	
	R+SM	90.7	44.5	16.5	16.8	128.8	183.9	481.6	75.9	21.8	8.1	77.7	40.6	236.7	460.8
		1971 - 1972							1972 - 1973						
	R	47.5	69.6	16.8	22.6	22.9	61.2	240.5	58.4	60.7	11.9	15.0	100.3	85.6	332.0
	S	29.7	45.5	45.5	87.1	65.0	8.1	280.9	12.2	86.1	18.8	30.5	16.8	6.1	170.4
	P	77.2	115.1	62.2	109.7	87.9	69.3	521.5	70.6	146.8	30.7	45.5	117.1	91.7	502.4
	SSBM	0.0	16.3	35.3	72.4	153.7	174.7		0.0	0.8	58.7	21.6	32.0	0.0	
	SSEM	16.3	35.3	72.4	153.7	174.7	0.0		0.8	58.7	21.6	32.0	0.0	0.0	
	SM	13.5	26.4	8.6	5.8	43.9	182.9		11.4	28.2	56.1	20.1	48.8	6.1	
	R+SM	61.0	96.0	25.4	28.4	66.8	244.1	521.5	69.9	88.9	68.1	35.0	149.1	91.7	502.4

Table 16 (cont'd)

Station		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
		1967 - 1968							1968 - 1969						
McLaughlin	R														
	S														
	P														
	SSBM														
	SSEM														
	SM														
	R+SM														
		1969 - 1970							1970 - 1971						
	R	101.8	0.0	0.0	11.2	22.6	75.9	211.6	73.2	12.2	0.0	3.0	0.2	33.0	121.7
	S	18.5	26.9	54.9	57.1	23.4	5.6	186.4	1.8	38.6	46.0	49.8	31.7	3.0	170.9
	P	120.4	26.9	54.9	68.3	46.0	81.5	398.0	74.9	50.8	46.0	52.8	32.0	36.1	292.6
	SSBM	0.0	17.8	40.6	89.4	138.1	128.2		0.0	2.0	35.6	71.5	107.3	108.1	
	SSEM	17.8	40.6	89.4	138.1	128.2	0.0		2.0	35.6	71.5	107.3	108.1	0.0	
	SM	0.8	4.1	6.1	8.4	33.3	133.8		1.8	3.0	10.0	14.0	31.0	121.2	
	R+SM	102.6	4.1	6.1	19.6	55.9	209.7	398.0	74.9	15.2	10.0	17.0	31.2	144.2	292.6
		1971 - 1972							1972 - 1973						
	R	28.4	81.0	19.6	0.0	10.7	37.3	177.0	56.6	58.2	21.8	16.0	103.4	74.4	330.4
	S	26.9	20.8	27.2	71.9	45.7	5.6	198.1	4.6	48.3	10.7	15.0	14.2	2.0	94.7
	P	55.4	101.9	46.7	71.9	56.4	42.9	375.2	61.2	106.4	32.5	31.0	117.6	76.5	425.2
	SSBM	0.0	10.4	16.5	43.7	104.6	124.7		0.0	0.0	12.8	2.4	15.0	0.0	
	SSEM	10.4	16.5	43.7	104.6	113.7	0.0		0.0	12.8	2.4	15.0	0.0	0.0	
	SM	16.5	17.7	0.0	11.0	36.6	130.3		4.6	35.5	21.1	2.3	29.2	2.0	
	R+SM	45.0	95.8	19.6	11.0	47.2	156.6	375.2	61.2	93.7	43.0	18.3	132.6	76.4	425.2

Table 16 (cont'd)

Station		1967 - 1968							1968 - 1969						
		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
Mostert	R	67.6	55.9	9.4	25.4	35.8	24.9	218.9	112.8	57.9	49.0	11.4	29.7	89.7	350.5
	S	6.3	4.6	60.7	8.4	18.3	0.0	98.3	2.0	32.0	14.2	1.0	2.0	0.0	51.3
	P	73.9	60.4	70.1	33.8	54.1	24.9	317.2	114.8	89.9	63.2	12.4	31.8	89.7	401.8
	SSBM	0.0	0.0	1.5	49.8	21.1	0.0		0.0	0.0	32.0	0.0	0.0	2.0	
	SSEM	0.0	1.5	49.8	21.1	0.0	0.0		0.0	32.0	0.0	0.0	2.0	0.0	
	SM	6.3	3.0	12.4	37.1	39.9	0.0		2.0	0.0	46.2	1.0	0.0	2.0	
	R+SM	73.9	58.9	21.8	62.5	75.2	24.9	317.2	114.8	57.9	95.3	12.4	29.7	91.7	401.8
		1969 - 1970							1970 - 1971						
	R	84.3	39.6	6.6	24.6	47.7	66.8	269.7	52.1	24.9	9.7	57.1	6.3	29.7	179.8
	S	12.7	18.8	30.5	5.1	4.6	0.0	71.6	0.0	36.3	21.6	21.6	20.8	0.0	100.3
	P	97.0	58.4	37.1	29.7	52.3	66.8	341.4	52.1	61.2	31.2	78.7	27.2	29.7	280.1
	SSBM	0.0	12.7	15.2	29.2	17.5	0.0		0.0	0.0	30.7	45.2	37.3	0.0	
	SSEM	12.7	15.2	29.2	17.5	0.0	0.0		0.0	30.7	45.2	37.3	0.0	0.0	
	SM	0.0	16.3	16.5	16.8	22.1	0.0		0.0	5.6	7.1	31.0	56.6	0.0	
	R+SM	84.3	55.9	23.1	41.4	69.9	66.8	341.4	52.1	30.5	16.8	88.1	63.0	29.7	280.1
		1971 - 1972							1972 - 1973						
	R	45.7	66.5	11.7	24.1	52.6	60.7	261.4	66.8	80.0	32.8	18.0	106.2	69.6	373.4
	S	9.1	35.0	9.9	33.3	29.0	7.1	123.4	8.9	33.0	2.5	15.7	1.0	0.0	61.2
	P	54.9	101.6	21.6	57.4	81.5	67.8	384.8	75.7	113.0	35.3	33.8	107.2	69.6	434.6
	SSBM	0.0	7.1	14.7	14.5	31.2	0.0		0.0	1.0	0.0	2.5	12.7	0.0	
	SSEM	7.1	14.7	14.5	31.2	0.0	0.0		1.0	0.0	2.5	12.7	0.0	0.0	
	SM	2.0	27.4	10.2	19.6	57.1	7.1		7.9	34.0	0.0	5.6	13.7	0.0	
	R+SM	47.8	94.0	21.8	43.7	109.7	67.8	384.8	74.7	114.0	32.8	23.6	119.9	69.6	434.6

Table 16 (cont'd)

Station		1967 - 1968							1968 - 1969						
		Nov	Dec	Jan	Feb	Mar	Apr	Total	Nov	Dec	Jan	Feb	Mar	Apr	Total
Orono	R	74.4	53.1	13.0	28.4	34.5	26.4	229.9	91.4	35.6	39.0	0.0	25.9	88.6	281.4
	S	19.6	23.6	60.2	26.4	23.4	0.0	153.2	30.2	52.1	25.1	20.8	4.3	0.0	132.6
	P	94.0	76.7	73.1	54.9	57.9	26.4	383.0	121.7	87.9	64.8	20.8	30.2	88.6	414.0
	SSBM	0.0	1.8	15.2	58.2	48.5	00		0.0	2.8	49.0	0.0	9.9	3.6	
	SSEM	1.8	15.2	58.2	48.5	0.0	0.0		2.8	49.0	0.0	9.9	3.6	0.0	
	SM	17.8	10.2	17.3	36.1	71.9	0.0		27.4	5..8	74.2	10.9	10.7	3.6	
	R+SM	92.2	63.2	30.2	64.5	106.4	26.4	383.0	118.9	41.7	113.8	10.9	36.6	92.2	414.0
		1969 - 1970							1970 - 1971						
	R	81.0	35.8	6.9	22.3	51.1	53.3	250.4	61.2	37.1	22.4	48.0	0.0	28.7	197.4
	S	8.9	25.7	58.4	40.9	13.7	7.1	154.7	2.5	53.3	36.1	67.3	29.2	0.0	188.5
	P	89.9	61.5	65.3	63.2	64.8	60.4	405.1	63.7	90.4	58.4	115.3	29.7	28.7	385.8
	SSBM	0.0	8.9	25.6	74.4	105.4	37.1		0.0	0.0	45.2	78.2	135.6	110.2	
	SSEM	8.9	25.6	74.4	105.4	37.1	0.0		0.0	45.2	78.2	135.6	110.2	0.0	
	SM	0.0	8.9	9.6	10.2	82.0	44.2		2.5	8.1	3.0	10.2	54.6	110.2	
	R+SM	81.0	44.7	16.5	32.5	133.1	97.5	405.1	63.7	45.2	25.4	58.2	54.6	138.9	385.8
		1971 - 1972							1972 - 1973						
	R	44.7	57.7	2.5	25.4	44.4	66.8	241.5	56.6	77.5	34.3	14.0	84.8	90.2	357.4
	S	21.6	33.0	41.9	52.1	45.7	8.9	203.2	11.4	57.9	7.6	19.1	0.0	0.0	96.0
	P	66.3	90.7	44.4	77.5	90.2	75.7	444.7	68.1	135.4	41.9	33.0	84.8	90.2	453.4
	SSBM	0.0	15.2	19.0	32.8	75.9	82.8		0.0	0.0	16.8	3.8	19.8	0.0	
	SSEM	15.2	19.0	32.8	75.9	82.8	0.0		0.0	16.8	3.8	19.8	0.0	0.0	
	SM	6.3	29.2	28.2	8.9	38.6	91.7		11.4	40.9	20.8	3.0	19.8	0.0	
	R+SM	51.1	86.9	30.7	34.3	83.1	158.5	444.7	68.1	118.4	55.1	17.0	104.6	90.2	453.4

Table 16 (cont'd)

Station		1967 - 1968 Nov	Dec	Jan	Feb	Mar	Apr	Total	1968 - 1969 Nov	Dec	Jan	Feb	Mar	Apr	Total
Tyrone	R	78.0	48.3	12.2	29.7	39.9	25.9	233.9	91.9	58.2	54.9	3.0	35.6	91.7	335.3
	S	18.5	19.6	48.8	16.5	21.1	0.0	124.5	21.3	24.6	17.8	15.2	0.0	81.5	
	P	96.5	67.8	61.0	46.2	61.0	25.9	358.4	113.3	82.8	72.6	18.3	38.1	91.7	416.8
	SSBM	0.0	0.0	15.0	51.3	43.7	0.0		0.0	0.0	24.1	0.0	11.2	2.5	
	SSEM	0.0	15.0	51.3	43.7	0.0	0.0		0.0	24.1	0.0	11.2	2.5	0.0	
	SM	18.5	4.6	12.4	24.1	64.8	0.0		21.3	0.5	41.9	4.1	11.2	2.5	
	R+SM	96.5	52.8	24.6	53.8	104.6	25.9	358.4	113.3	58.7	96.8	7.1	46.7	94.2	416.8

Station		1969 - 1970 Nov	Dec	Jan	Feb	Mar	Apr	Total	1970 - 1971 Nov	Dec	Jan	Feb	Mar	Apr	Total
	R	85.1	16.8	6.6	18.3	65.8	72.1	264.7	66.3	30.5	8.4	61.5	24.9	32.3	223.8
	S	9.6	42.7	45.2	13.7	6.6	5.1	122.9	2.5	47.2	65.5	49.5	57.4	0.0	222.2
	P	94.7	59.4	51.8	32.0	72.4	77.2	387.6	68.8	77.7	73.9	111.0	82.3	32.3	446.0
	SSBM	0.0	9.6	43.7	74.9	81.5	16.0		0.0	0.0	40.1	105.7	136.6	145.8	
	SSEM	9.6	43.7	74.9	81.5	16.0	0.0		0.0	40.1	105.7	136.6	145.8	0.0	
	SM	0.0	8.6	14.0	7.1	71.9	21.1		2.5	7.1	0.0	18.5	48.5	146.0	
	R+SM	85.1	25.4	20.6	25.4	137.7	93.2	387.6	68.8	37.6	8.4	80.0	73.4	178.3	446.0

Station		1971 - 1972 Nov	Dec	Jan	Feb	Mar	Apr	Total	1972 - 1973 Nov	Dec	Jan	Feb	Mar	Apr	Total
	R	39.4	71.4	14.7	19.6	66.5	64.5	276.1	63.5	62.0	37.8	22.9	114.0	97.5	397.8
	S	20.8	39.6	44.5	77.2	57.4	5.1	244.6	9.1	54.3	3.6	17.8	3.8	1.5	90.1
	P	60.2	111.0	59.2	96.8	123.9	69.6	520.7	72.6	116.3	41.4	40.6	117.9	99.1	487.9
	SSBM	0.0	10.2	28.2	69.6	139.7	170.7		0.0	1.0	28.4	0.0	13.7	0.0	
	SSEM	10.2	28.2	69.6	139.7	170.7	0.0		1.0	28.4	0.0	13.7	0.0	0.0	
	SM	10.7	21.6	3.0	7.1	26.4	175.8		8.1	26.9	32.0	4.1	17.5	1.5	
	R+SM	50.0	93.0	17.8	26.7	93.0	240.3	520.7	71.6	88.9	69.8	26.9	131.6	99.1	487.9

Table 17. Monthly and Annual Modified Precipitation Input Due to Snow Accumulation and Melt as Computed from the Thiessen Polygon Network for Various Basins and Sub-Basins in the Study Area

All Values in mm

Basin	Year	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Annual	Year	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Annual
Bowmanville	1968	*	*	*	*	*	*	*	1971	8.9	44.5	48.1	178.8	50.7	94.3	859.7
Basin	1969	*	*	*	*	91.3	21.0	*	1972	15.3	13.9	60.6	215.1	64.9	89.3	928.0
02HD006	1970	11.0	19.1	86.9	165.9	70.4	24.2	815.7	1973	70.1	27.7	133.4	86.1	101.8	48.5	913.8
Soper	1968	*	*	*	*	*	*	*	1971	11.0	53.7	70.1	147.2	47.7	86.1	825.1
Basin	1969	*	*	*	*	90.3	32.6	*	1972	26.7	25.1	94.3	175.0	73.4	85.0	999.0
02HD007	1970	18.7	32.9	114.2	108.1	63.9	48.3	793.1	1973	70.3	25.6	139.6	78.0	89.4	44.3	856.6
Wilmot	1968	31.5	57.8	106.8	27.5	112.2	47.7	750.7	1971	11.5	51.7	49.7	185.6	54.0	89.8	820.7
Basin	1969	94.1	10.9	49.5	97.7	88.5	42.0	848.1	1972	32.7	23.4	74.4	189.3	66.9	78.5	991.1
02HD009	1970	17.4	25.1	130.1	130.0	66.5	33.8	822.0	1973	55.9	28.1	131.7	84.8	93.5	44.8	844.4
B-1, B-2	1968	*	*	*	*	*	*	*	1971	10.0	17.0	31.2	144.2	45.0	95.8	789.2
	1969	*	*	*	*	102.6	4.1	*	1972	19.6	11.0	47.2	156.6	61.2	93.7	877.0
	1970	6.1	19.6	55.9	209.8	74.9	15.2	799.3	1973	43.0	18.3	132.6	76.4	105.2	39.6	874.4
B-3	1968	*	*	*	*	*	*	*	1971	7.9	74.6	68.9	185.6	51.8	93.1	909.2
	1969	*	*	*	*	84.4	28.0	*	1972	15.9	23.0	84.8	245.0	70.4	93.0	1066.9
	1970	18.5	23.0	128.0	107.8	68.4	35.1	795.0	1973	71.9	29.5	137.6	97.3	108.2	54.0	969.6
B-4	1968	*	*	*	*	*	*	*	1971	9.0	47.2	50.0	164.4	48.3	94.4	850.0
	1969	*	*	*	*	93.4	40.4	*	1972	17.8	17.4	67.4	201.2	66.5	92.8	976.9
	1970	12.6	21.7	93.9	155.9	71.6	25.7	797.2	1973	57.5	23.7	132.4	87.1	107.2	43.3	921.6

Table 17 (cont'd)

Basin	Year	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Annual	Year	Jan.	Feb.	Mar.	Apr.	Nov.	Dec.	Annual
S-1, W-1,	1968	24.4	52.1	148.3	29.2	126.0	49.8	853.0	1971	8.1	77.7	40.6	236.7	61.0	96.0	889.6
W-2	1969	108.5	11.2	73.2	100.6	90.6	44.5	895.6	1972	25.4	28.4	66.8	244.1	69.9	88.9	1041.2
	1970	16.5	16.8	128.8	183.9	75.9	21.8	801.0	1973	68.1	35.0	149.1	91.7	101.6	46.5	921.2
S-2	1968	*	*	*	*	*	*	*	1971	12.1	61.1	65.9	177.6	49.1	88.6	889.5
	1969	*	*	*	*	88.8	24.9	*	1972	22.3	22.1	89.5	230.3	72.8	81.8	1043.8
	1970	18.8	23.5	132.0	112.0	68.7	36.9	794.2	1973	77.4	27.4	140.2	90.2	103.4	48.2	961.4
S-3	1968	31.9	58.1	122.1	28.0	116.6	45.1	805.5	1971	7.2	50.1	51.9	208.0	51.2	86.3	846.3
	1969	97.7	10.8	56.1	98.6	93.8	29.4	837.0	1972	29.5	21.6	82.7	221.7	73.8	74.2	1011.6
	1970	17.6	20.5	130.7	146.3	71.4	32.3	795.0	1973	81.0	28.8	152.0	82.3	95.8	40.9	899.3
S-4	1968	25.7	63.9	86.6	25.7	113.7	49.1	724.8	1971	6.5	83.0	60.9	76.2	46.5	87.4	767.2
	1969	95.5	13.9	32.7	93.0	86.7	43.0	792.5	1972	17.4	14.2	111.1	138.5	73.9	101.5	938.9
	1970	20.2	35.4	100.5	83.5	58.4	37.5	758.2	1973	53.4	25.4	120.2	74.4	86.3	96.1	795.9
W-3	1968	29.7	49.2	73.5	26.2	94.5	44.1	638.4	1971	9.5	25.8	54.6	127.6	51.0	88.6	738.5
	1969	66.3	15.3	37.0	96.4	87.5	44.2	813.4	1972	40.9	13.9	71.3	144.9	59.4	110.4	940.4
	1970	18.3	30.6	132.3	90.6	58.7	39.9	799.3	1973	43.1	24.2	107.8	76.2	81.0	44.1	763.3

* indicates incomplete records

Table 18. Names, Symbols, Parent Material, Description and Hydraulic Characteristics of Various Soil Types in the Study Area (Webber et al, 1946, 1966)

Soil Name	Symbol	Parent Material	Description of Surface and Subsoil Materials	Drainage	Dry Limit 15-bar %	Wet Limit 0.33 bar %
Bondhead Loam	Bl	Till	Grey brown loam over light brown loam over brownish clay loam over grey stony loam; high in lime, few stones.	Good	4.80	23.60
Bondhead Fine Sandy Loam	Bsl	Till	Grey brown sandy loam and light brown sandy loam over brownish loam underlain by grey stony calcareous loam and sandy loam; few stones.	Good	4.80	23.60
Otonabee Loam Steep Phase	Ol-s	Till	A shallow soil over grey calcareous stony loam; variable surface texture; limited in use by very steep slopes.	Excessive	5.00	23.30
Dondonald Sandy Loam	Dsl	Till	Grey brown sandy loam over yellowish sandy loam over brown loam underlain by compact stony calcareous loam; stonefree.	Good	5.90	15.10
Darlington Loam	Dal	Till	Dark grey brown heavy loam and greyish loam over weak reddish brown clay loam underlain by grey stony compact loam; high in lime; few stones.	Fair to Good	5.90	15.10

Table 18 (cont'd)

Soil Name	Symbol	Parent Material	Description of Surface and Subsoil Materials	Drainage	Dry Limit 15-bar %	Wet Limit 0.33 bar %
Darlington Sandy Loam	Dasl	Till	Light grey brown sandy loam over yellow brown sandy loam and brownish loam underlain by grey compact stony loam or sandy loam.	Good	5.90	15.10
Guerin Loam	Gul	Till	Dark grey brown loam grading into a mottled greyish brown loam and finally grey stony loam; some stones.	Poor	5.90	15.10
Lyons Loam	Ll	Till	Dark greyish brown loam over highly mottled greyish stony loam; numerous boulders and stones.	Poor	10.10	21.10
Pontypool Sandy Loam	Psl	Glacio-fluvial	Light brownish sandy loam and yellow brown sand over dark brown loam underlain by grey coarse calcareous sand; some stones.	Good	7.00	15.70
Pontypool Sand	Ps	Glacio-fluvial	Light grey brown sand and yellow sand over grey coarse calcaseous sand and stony sand; some boulders.	Excessive	7.00	15.70
Brighton Sandy Loam	Brs	Deltaic or outwash	Light grey brown sandy loam and yellow sand over some brownish loam or sandy loam underlain by grey coarse calcaseous stratified sand; stonefree.	Good	5.90	15.10
Brighton Sand	Bs	Deltaic or outwash	Light grey brown sand and yellow sand over coarse calcaseous sand; stonefree	Good	5.90	15.10
Brighton Gravelly Sand	Bg	Deltaic or outwash	Light grey brown coarse sand with large quantities of gravel underlain by grey coarse stratified gravel.	Good	5.90	15.10

Table 18 (cont'd)

Soil Name	Symbol	Parent Material	Description of Surface and Subsoil Materials	Drainage	Dry Limit 15-bar %	Wet Limit 0.33 bar %
Tecumseth Sandy Loam	Tsl	Deltaic or outwash	Dark brown sandy loam over yellow sand grading into grey sand with rusty mottling and finally grey coarse calcareous sandy loam; stonefree.	Poor	12.80	21.50
Granby Sandy Loam	Gsl	Deltaic or outwash	Dusky brown sand loam grading into rusty mottled grey coarse calcareous sand and sandy loam; stonefree.	Very Poor	5.90	15.10
Newcastle Loam	Nl	Lacustrine	Grey brown loam over light brown loam underlain by weak reddish brown clay loam, silt and loam; high in lime; some stones.	Fair to Good	10.10	21.10
Newcastle Clay Loam	Ncl	Lacustrine	Dark grey brown clay loam and light brown loam over weak reddish brown clay over silt and clay; high in lime; relatively stonefree.	Fair to Good	10.10	21.10
Smithfield Clay Loam	Scl	Lacustrine	Dark grey brown clay loam over brownish clay grading into grey lime clay; stonefree.	Fair to Poor	10.10	21.10
Muck	M	Organic	Black organic material of various depth in different stages of decomposition.	Very Poor	2.00	50.00

Table 19. Estimated Monthly and Annual Potential Evapotranspiration Within the Study Area Based on Thornthwaite Method for the Period 1968-1973

(All Values in mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1968	0	0	0.2	39.1	65.0	103.9	126.7	111.8	86.4	45.0	7.6	0	585.7
1969	0	0	0	35.6	67.3	98.6	126.7	121.9	77.3	37.6	12.9	0	577.9
1970	0	0	0	34.5	70.4	102.1	128.3	117.3	76.2	47.0	13.5	0	589.3
1971	0	0	0	21.1	66.3	103.6	112.8	109.5	85.1	57.9	2.5	0	558.0
1972	0	0	0	15.7	79.5	97.8	125.0	107.7	80.8	27.4	2.3	0	536.2
1973	0	0	13.7	28.7	61.5	110.2	129.3	125.5	74.7	44.2	9.6	0	597.4

Estimated long-term, mean annual potential evapotranspiration = 574.2

Table 20. Areal Distribution of Various Types of Soils in the Bowmanville Creek Basin and Sub-basins, their Areal Weights, their Contribution to the Soil Moisture Capacity and Estimates of the Soil Moisture Capacity by Basin and Sub-basin Based on an Assumed Soil Profile Depth of One Meter.

Soil	B-1			B-2*			B-3			B-4			02HD006		
Symbol	A	AW	WMC	A	AW	WMC	A	AW	WMC	A	AW	WMC	A	AW	WMC
Bl	2.07	0.33	62.04	6.92	0.34	63.92	3.94	0.38	71.44	0.41	0.02	3.76	14.74	0.17	31.96
Bl+Bsl													0.75	0.01	1.88
Bsl													9.56	0.11	20.68
Ol - s				4.91	0.24	43.92							7.95	0.09	16.47
Dsl	1.14	0.18	16.56	3.55	0.17	15.64	3.96	0.38	34.96	10.02	0.37	34.04	190.29	0.22	20.24
Dal							1.04	0.10	9.20	5.88	0.23	2.16	14.40	0.17	15.64
Gul							0.13	0.01	0.92	0.96	0.04	3.68	1.56	0.02	1.84
Ps	3.06	0.49	42.63	3.06	0.15	13.05	1.32	0.13	11.31	8.78	0.34	29.58	13.16	0.15	13.05
Bg													1.94	0.02	1.84
Gsl													0.44	0.01	0.92
Nl+Ncl+Scl													0.69	0.01	1.16
M				2.02	0.10	48.00							2.02	0.02	9.60
Total	6.27	1.00	121.23	20.46	1.00	184.53	10.39	1.00	127.83	26.05	1.00	92.22	86.50	1.00	135.28

* = Sub-basin B-2 includes sub-basin B-1;
A = Area, km^2;
AW = Areal weight of soil type, dimensionless;
WMC = Contribution of each soil type to the soil moisture capacity of the basin (mm);

Table 21. Areal Distribution of Various Types of Soils in the Soper Creek Basin and Sub-basins, their Areal Weights, their Contribution to the Soil Moisture Capacity and Estimates of the Soil Moisture Capacity by Basin and Sub-basin Based on an Assumed Soil Profile Depth of One Meter.

Soil	S-1			S-2			S-3*			S-4			02HD007		
Symbol	A	AW	WMC	A	AW	WMC	A	AW	WMC	A	AW	WMC	A	AW	WMC
Bl+Bsl				10.28	0.65	122.2	5.08	0.30	56.40				17.92	0.23	43.24
Ol - s	0.36	0.08	14.64				1.32	0.08	14.64				1.32	0.02	3.66
Dsl	3.70	0.79	72.68	3.47	0.22	20.24	8.15	0.48	44.16				11.62	0.15	13.80
Dal				0.47	0.03	2.76	0.75	0.04	3.68				1.22	0.02	1.84
Dasl										1.53	0.11	10.12	5.80	0.08	7.36
Gul													1.71	0.02	1.84
Ll													0.28	0.003	0.33
Psl	0.62	0.13	11.31				0.62	0.04	3.48				0.62	0.01	0.87
Ps				1.42	0.09	7.83							1.42	0.02	1.74
Brs+Bg							1.11	0.06	5.52	2.92	0.21	19.32	4.03	0.05	4.60
Bs+Bg				0.18	0.01	0.92							11.86	0.16	14.72
Tsl													0.26	0.003	0.26
Gsl													0.57	0.01	0.92
Ncl+Scl										9.48	0.68	74.80	16.32	0.22	24.20
M													0.28	0.003	1.44
Total	4.68	1.00	98.63	15.80	1.00	153.95	17.03	1.00	127.88	13.93	1.00	104.24	75.22	1.00	120.82

* = Sub-basin S-3 includes sub-basin S-1;

See Table 21 for other symbols and units.

Table 22. Areal Distribution of Various Types of Soils in the Wilmot Creek Basin and Sub-basins, their Areal Weights, their Contribution to the Soil Moisture Capacity and Estimates of the Soil Moisture Capacity by Basin and Sub-basin Based on an Assumed Soil Profile Depth of One Meter.

Soil	W-1			W-2*			W-3			02HD009		
Symbol	A	AW	WMC	A	AW	WMC	A	AW	WMC	A	AW	WMC
Bl+Bsl										21.65	0.27	50.76
Bsl							14.22	0.69	129.72	14.22	0.17	31.96
Ol - s	2.10	0.19	34.77	2.64	0.10	18.30	0.62	0.03	5.49	3.26	0.03	5.49
Dsl	1.16	0.11	10.12	13.65	0.50	46.00				17.20	0.21	19.32
Ll							0.78	0.03	3.30	0.78	0.01	1.10
Psl+Ps	7.54	0.70	60.90	10.67	0.39	33.93				10.67	0.13	11.31
Brs				0.15	0.01	0.92				0.15	0.01	0.92
Brs+Bs							3.57	0.17	15.64	3.57	0.04	3.68
Brs+Bg										4.87	0.06	5.52
Gsl							0.85	0.04	3.68	0.85	0.01	0.92
Nl							0.85	0.04	4.40	5.36	0.06	6.60
Total	10.80	1.00	105.79	27.11	1.00	99.15	20.89	1.00	162.23	82.58	1.00	137.58

* = Sub-basin W-2 includes sub-basin W-1;

See Table 21 for other symbols and units

Table 23. Estimates of Monthly, Annual and 6-Year Mean Actual Evapotranspiration for Various Basins and Sub-basins in the Study Area for the Period 1968-1973
(All values in mm)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	6-Year Mean
Bowmanville Cr. 02HD006	1968	0.0	0.0	0.2	39.1	65.0	103.9	63.3	99.3	86.4	45.0	7.6	0.0	509.8	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	121.7	96.5	20.8	37.6	13.0	0.0	491.0	
	1970	0.0	0.0	0.0	34.5	70.4	99.3	96.8	54.3	76.2	47.0	13.5	0.0	492.0	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	112.8	86.4	60.6	47.5	2.5	0.0	500.8	
	1972	0.0	0.0	0.0	15.7	79.5	96.8	110.0	107.0	78.7	27.4	2.3	0.0	518.1	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	80.5	71.4	52.1	44.2	9.6	0.0	471.9	497.3
Soper Cr. 02HD007	1968	0.0	0.0	0.2	39.1	65.0	103.9	58.7	83.1	76.7	45.0	7.6	0.0	479.3	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	119.6	108.2	23.4	37.6	13.0	0.0	503.4	
	1970	0.0	0.0	0.0	34.5	70.4	103.6	90.2	50.3	55.1	47.0	13.5	0.0	464.4	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	108.2	80.8	59.2	56.9	2.5	0.0	498.7	
	1972	0.0	0.0	0.0	15.7	79.5	93.7	119.6	107.7	77.4	27.4	2.3	0.0	523.3	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	60.7	73.1	49.5	44.2	9.6	0.0	451.1	486.7
Wilmot Cr. 02HD009	1968	0.0	0.0	0.2	39.1	65.0	83.9	58.9	72.8	71.1	44.9	7.6	0.0	443.7	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	105.0	108.6	44.9	37.6	12.9	0.0	510.4	
	1970	0.0	0.0	0.0	34.5	70.4	101.8	100.6	48.3	67.1	47.0	13.5	0.0	483.2	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	101.6	71.1	55.1	54.6	2.5	0.0	476.0	
	1972	0.0	0.0	0.0	15.7	79.5	95.8	103.0	107.7	78.0	27.4	2.3	0.0	509.7	
	1973	0.0	0.0	13.7	28.7	61.7	100.5	93.7	65.5	48.8	44.2	9.6	0.0	466.4	481.6
B-1	1968	0.0	0.0	0.2	39.1	65.0	103.9	125.7	110.9	86.4	45.0	7.6	0.0	583.8	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	122.7	88.6	18.8	37.6	12.9	0.0	482.0	
	1970	0.0	0.0	0.0	34.5	70.4	94.5	94.5	62.7	76.2	47.0	13.5	0.0	493.3	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	90.8	87.0	69.0	41.4	2.5	0.0	481.7	
	1972	0.0	0.0	0.0	15.7	79.5	90.7	100.5	86.6	63.1	27.4	2.3	0.0	465.8	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	84.8	67.8	52.1	44.2	9.6	0.0	472.2	496.5

Table 23 (cont'd)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	6-Year Mean
B-2	1968	0.0	0.0	0.2	39.1	65.0	103.9	125.7	111.0	86.4	45.0	7.6	0.0	583.9	
	1969	0.0	0.0	0.0	35.5	67.3	98.5	122.7	88.6	18.8	37.6	12.9	0.0	481.7	
	1970	0.0	0.0	0.0	34.5	70.4	94.5	94.5	68.7	76.2	47.0	13.5	0.0	499.3	
	1971	0.0	0.0	0.0	21.1	56.3	103.6	92.8	66.9	68.8	41.4	2.5	0.0	453.5	
	1972	0.0	0.0	0.0	11.7	79.5	87.8	80.6	87.7	63.1	27.4	2.3	0.0	440.1	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	84.8	67.8	52.1	44.2	9.6	0.0	472.2	488.5
B-3	1968	0.0	0.0	0.2	39.1	65.0	103.9	70.6	93.5	86.4	45.0	7.6	0.0	511.3	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	120.6	100.8	30.5	37.6	12.9	0.0	503.8	
	1970	0.0	0.0	0.0	34.5	70.4	100.6	102.6	45.0	75.9	47.0	13.5	0.0	489.7	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	92.0	94.5	71.1	49.5	2.5	0.0	500.6	
	1972	0.0	0.0	0.0	15.7	79.5	94.7	109.2	107.7	80.8	27.4	2.3	0.0	517.3	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	78.5	87.1	55.1	44.2	9.6	0.0	488.6	501.9
B-4	1968	0.0	0.0	0.2	39.1	65.0	103.9	44.7	101.6	86.4	45.0	7.6	0.0	493.8	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	115.1	79.5	16.5	37.6	12.9	0.0	463.0	
	1970	0.0	0.0	0.0	34.5	70.4	50.8	87.5	51.8	76.2	47.0	13.5	0.0	431.8	
	1971	0.0	0.0	0.0	21.1	56.3	83.6	72.8	65.8	69.1	44.7	2.5	0.0	415.6	
	1972	0.0	0.0	0.0	15.7	79.5	93.5	79.5	97.7	80.0	27.4	2.3	0.0	475.6	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	57.1	75.4	52.6	44.2	9.6	0.0	453.0	455.5
S-1	1968	0.0	0.0	0.2	39.1	65.0	103.9	24.9	96.0	83.1	45.0	7.6	0.0	464.8	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	110.4	108.1	17.3	37.6	12.9	0.0	486.7	
	1970	0.0	0.0	0.0	34.5	70.4	55.6	64.5	54.7	62.5	47.0	13.5	0.0	402.7	
	1971	0.0	0.0	0.0	21.1	66.3	105.3	101.2	80.7	56.1	48.5	2.5	0.0	481.6	
	1972	0.0	0.0	0.0	15.7	79.5	97.0	88.6	107.7	77.5	27.4	2.3	0.0	446.3	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	80.3	77.5	55.5	44.2	9.6	0.0	481.2	468.9
S-2	1968	0.0	0.0	0.2	39.1	65.0	103.9	85.1	89.9	85.1	45.0	7.6	0.0	520.9	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	122.9	109.5	28.4	37.6	12.9	0.0	513.7	
	1970	0.0	0.0	0.0	34.5	70.4	100.8	95.5	37.2	57.6	47.0	13.5	0.0	456.6	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	112.8	103.6	67.1	51.6	2.5	0.0	528.8	
	1972	0.0	0.0	0.0	15.7	79.5	96.0	114.0	107.7	80.8	27.4	2.3	0.0	523.7	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	81.7	85.6	68.3	44.2	9.6	0.0	503.6	507.9

Table 23 (cont'd)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	6-Year Mean
S-3	1968	0.0	0.0	0.2	39.1	65.0	80.9	17.0	87.9	82.0	45.0	7.6	0.0	424.5	
	1969	0.0	0.0	0.0	35.6	67.3	75.5	102.6	96.4	14.3	37.6	12.9	0.0	442.2	
	1970	0.0	0.0	0.0	34.5	70.4	78.2	70.8	46.7	57.5	47.0	13.5	0.0	418.6	
	1971	0.0	0.0	0.0	21.1	66.3	87.3	85.0	63.2	54.1	47.9	2.5	0.0	427.4	
	1972	0.0	0.0	0.0	15.7	79.5	95.5	102.3	107.7	78.2	27.4	2.3	0.0	508.6	
	1973	0.0	0.0	13.7	28.7	61.5	90.2	65.2	78.2	48.8	44.2	9.6	0.0	440.1	443.6
S-4	1968	0.0	0.0	0.2	39.1	65.0	103.9	33.5	78.0	67.8	45.0	7.6	0.0	440.1	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	115.8	98.5	24.9	37.6	12.9	0.0	491.1	
	1970	0.0	0.0	0.0	34.5	70.4	101.8	103.4	46.5	47.0	47.0	13.5	0.0	464.1	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	99.3	90.7	53.1	57.9	2.5	0.0	494.4	
	1972	0.0	0.0	0.0	15.7	79.5	91.9	112.4	107.7	71.4	27.4	2.3	0.0	508.3	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	49.8	64.3	48.8	44.2	9.6	0.0	430.8	471.5
W-1	1968	0.0	0.0	0.2	39.1	65.0	103.9	82.3	97.0	80.1	45.0	7.6	0.0	520.1	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	104.7	110.1	44.4	37.6	12.9	0.0	511.2	
	1970	0.0	0.0	0.0	34.5	70.4	99.8	86.8	47.2	63.0	47.0	13.5	0.0	462.4	
	1971	0.0	0.0	0.0	21.1	66.3	111.8	110.2	88.9	57.7	49.0	2.5	0.0	507.5	
	1972	0.0	0.0	0.0	15.7	79.5	97.5	113.0	107.7	77.7	27.4	2.3	0.0	521.5	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	90.2	80.3	72.6	44.2	9.6	0.0	511.0	505.6
W-2	1968	0.0	0.0	0.2	39.1	65.0	103.9	50.3	96.0	83.1	45.0	7.6	0.0	490.2	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	100.4	108.1	17.3	37.6	12.9	0.0	477.7	
	1970	0.0	0.0	0.0	34.9	70.4	85.6	64.5	44.7	62.5	47.0	13.5	0.0	423.5	
	1971	0.0	0.0	0.0	21.1	66.3	110.2	106.2	75.7	56.1	48.5	2.5	0.0	487.6	
	1972	0.0	0.0	0.0	15.7	79.5	97.0	108.7	107.7	77.5	27.4	2.3	0.0	515.8	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	75.7	77.5	70.9	44.2	9.6	0.0	492.0	481.1
W-3	1968	0.0	0.0	0.2	39.1	65.0	73.9	63.4	72.4	54.2	45.0	7.6	0.0	420.6	
	1969	0.0	0.0	0.0	35.6	67.3	98.5	119.7	107.9	37.3	37.6	12.9	0.0	517.8	
	1970	0.0	0.0	0.0	34.5	70.4	102.1	121.9	55.4	48.8	47.0	13.5	0.0	492.6	
	1971	0.0	0.0	0.0	21.1	66.3	103.6	106.7	75.4	53.8	57.9	2.5	0.0	487.2	
	1972	0.0	0.0	0.0	15.7	79.5	94.2	114.0	107.7	79.0	27.4	2.3	0.0	520.2	
	1973	0.0	0.0	13.7	28.7	61.5	110.2	96.1	51.8	50.3	44.2	9.6	0.0	465.1	483.9

Table 24. Summary of Streamflow Gauging Stations in the Bowmanville, Soper and Wilmot Creeks Drainage Basin

Station Name	Station Number	Drainage Area Km^2	Location Latitude	Location Longitude	Period of Record from	Quality of Records
B-1 at Enfield	02HD211	6.27	44° 01' 40"	78° 49' 45"	April, 1967	Poor
B-2 at Eniskellen	02HD212	20.46	44° 01' 30"	78° 47' 00"	Jan., 1966	Fair to Good
B-3 at Hampton	02HD213	10.39	43° 58' 00"	78° 43' 30"		Extremely Poor
B-4 at Hampton	02HD214	26.05	43° 58' 05"	78° 43' 50"	Aug., 1966	Fair to Good
Bowmanville Creek	02HD006	86.50	43° 55' 18"	78° 42' 09"		Extremely Poor
S-1 at Tyrone	02HD221	4.68	44° 01' 00"	78° 41' 00"	April, 1968	Fair to Good
S-2 at Stephen Gulch	02HD222	15.80	43° 58' 30"	78° 40' 30"	Oct., 1966	Fair to Good
S-3 at Stephen Gulch	02HD223	17.03	43° 58' 35"	78° 40' 15"	Jan., 1966	Fair to Good
S-4 at Bowmanville	02HD224	13.93	43° 54' 40"	78° 39' 40"	April, 1966	Fair to Good
Soper Creek	02HD007	75.20	43° 54' 08"	78° 40' 21"	Oct., 1965	Fair to Good
W-1 above Leskard	02HD231	10.80	44° 02' 40"	78° 39' 00"	May, 1967	Fair to Good
W-2 above Leskard	02HD232	27.11	44° 00' 30"	78° 38' 20"	Nov., 1965	Fair to Good
W-3 below Orono	02HD233	20.89	43° 56' 30"	78° 37' 00"	Nov., 1967	Fair to Good
Wilmot Creek	02HD009	82.58	43° 55' 47"	78° 37' 06"	Oct., 1966	Fair to Good

Table 25. Mean, Maximum and Minimum Daily Flows, Ratio of Maximum to Minimum Daily Flows and their Dates of Occurrence for Various basins and Sub-basins within the Study Area.

Basin	Year	Mean Daily Flow m^3/sec	Maximum Daily Flow m^3/sec	Date	Minimum Daily FLow m^3/sec	Minimum Daily Flow mm	Date	Max. Daily Flow / Min. Daily Flow
B-2	1966	0.221	5.664	March, 1	0.062	0.254	July, 16	91.35
	1967	0.301	5.098	March, 27	0.074	0.310	July, 21	68.89
	1968	0.252	2.916	March, 18	0.082	0.345	Aug., 15	35.56
	1969	0.227	2.535	March, 21	0.088	0.371	Sept., 20	28.81
	1970	0.195	1.926	April, 9	0.088	0.371	Aug., 6	21.89
	1971	0.215	2.407	June, 28	0.082	0.345	Aug., 17	29.35
	1972	0.280	3.370	April, 13	0.093	0.394	July, 30	36.24
B-4	1966*	*	*	*	0.173?	0.573	Aug., 6	*
	1967	0.371	2.673	April, 2	0.212	0.704	July, 22	12.61
	1968	0.377	6.712	Feb., 2	0.195	0.648	Jan., 2	34.42
	1969	0.388	2.945	March, 18	0.212	0.704	July, 20	13.89
	1970	0.330	1.810	Feb., 2	0.142	0.469	March, 1	12.75
	1971	0.356	3.200	April, 9	0.184	0.610	July, 4	17.39
	1972	0.405	5.862	April, 13	0.184	0.610	March, 2	31.86
	1973	0.375	4.248	April, 1	0.176	0.582	July, 23	24.14
	1974							
	1975							
S-1	1968*	*	0.173?	April, 4	0.027	0.496	Aug., 5	6.41
	1969	0.059	0.484	March, 18	0.034	0.626	Sept. 4	14.23
	1970	0.059	0.445	April, 8	0.034	0.626	June, 7	13.09
	1971	0.051	0.425	April, 9	0.034	0.626	June 23	12.50
	1972	0.065	1.051	April, 13	0.034	0.626	Sep., 14	30.91
	1973	0.065	0.943	March, 4	0.037	0.678	Feb., 10	25.49
	1974	0.062	0.883	Jan., 27	0.031	0.574	July, 21	28.48
	1975*	*	*	*	*	*	*	*
S-2	1966*	*	*	*	*	*	*	*
	1967	0.238	2.801	March, 26	0.085	0.464	Sep., 11	32.95
	1968	0.204	2.285	Feb., 2	0.082	0.448	July, 22	27.86

Table 25 (cont'd)

S-2	1969	0.209	1.586	Jan., 24	0.051	0.278	Dec., 28	31.10
	1970	0.173	0.935	April, 20	0.048	0.263	Jan., 3	19.48
	1971	0.178	2.631	April, 2	0.071	0.386	Aug., 17	37.05
	1972	0.229	4.503	April, 13	0.088	0.479	Sept., 22	51.17
	1973	0.218	5.409	Mar., 4	0.068	0.371	Jul., 24	79.54
	1974	0.200	4.899	Mar., 5	0.076	0.417	Aug., 21	64.46
	1975*	*	*	*	*	*	*	*
S-3	1965*	*	*	*	*	*	*	*
	1966	0.221	6.117	Mar., 1	0.074	0.373	Jul., 23	82.66
	1967	0.227	1.940	Mar., 26	0.105	0.531	Sep., 5	18.48
	1968	0.234	2.747	Feb., 2	0.105	0.531	Aug., 5	26.16
	1969	0.229	2.107	Jan., 30	0.108	0.545	Jul., 24	19.51
	1970	0.215	0.864	Mar., 26	0.110	0.559	Aug., 13	7.85
	1971	0.222	2.152	Apr., 2	0.091	0.459	Aug., 13	23.65
	1972	0.255	3.030	Apr., 13	0.116	0.588	Jul., 31	26.12
	1973	0.255	2.274	Mar., 4	0.108	0.545	Jul., 17	21.05
	1974	0.263	3.200	Mar., 5	0.110	0.559	Aug., 25	29.09
	1975*	*	*	*	*	*	*	*
S-4	1966*	*	*	*	*	*	*	*
	1967	0.142	1.875	Mar., 24	0.009	0.057	Sep., 16	208.33
	1968	0.108	3.738	Feb., 2	0.009	0.056	Aug., 5	415.33
	1969	0.136	4.531	Jan., 30	0.012	0.074	Jul., 23	377.58
	1970	0.105	1.427	Mar., 5	0.006	0.035	Aug., 18	237.83
	1971	0.139	3.738	Feb., 27	0.009	0.056	Aug., 20	415.33
	1972*	0.159(est.)	4.899	Mar., 22	0.007	0.045	Feb., 2	699.86
	1973	0.147	4.163	Feb., 2	0.009	0.056	Sep., 12	462.55
	1974	0.175	8.411	Jan., 27	0.015	0.096	Aug., 22	560.73
	1975*	*	*	*	*	*	*	*
02HD007	1965*	*	*	*	0.175?		Aug., 16	*
	1966	0.699	12.064	Dec., 7	0.173	0.198	Jul., 18	69.73
	1967*	*	9.261?	Apr., 3	0.269?	0.309	Sep., 14	34.42
	1968*	*	*	*	*	*	*	*
	1969	1.016	16.369	Jan., 30	0.249	0.286	Jul., 24	65.74
	1970	0.794	7.080	Mar., 20	0.266	0.305	Aug., 9	26.62
	1971	0.814	14.585	Apr., 2	0.190	0.218	Aug., 7	76.76
	1972	1.005	18.238	Apr., 13	0.235	0.270	Sep., 7	77.61
	1973*	*	14.896?	Mar., 4	*	*	*	*

Table 25 (cont'd)

W-1	1967*	*	0.187?	Oct., 19	0.096	0.770	Sep., 6	1.95
	1968	0.116	0.357	Mar., 18	0.096	0.770	Aug., 5	3.72
	1969	0.125	0.360	Mar., 21	0.096	0.770	Sep., 4	3.75
	1970	0.119	0.249	Apr., 8	0.099	0.793	Aug., 18	2.52
	1971	0.110	0.229	Apr., 10	0.088	0.702	May, 30	2.60
	1972	0.113	0.456	Apr., 13	0.091	0.725	Jul., 29	5.01
	1973	0.125	0.532	Mar., 7	0.091	0.725	Jul., 24	5.95
	1974	0.136	0.629	Apr., 4	0.096	0.770	Aug., 29	6.55
	1975*	*	*	*	*	*	*	*
W-2	1965	*	*	*	*	*	*	*
	1966	0.300	3.313	Mar., 1	0.142	0.451	Jul., 22	2.20
	1967	0.354	1.518	Mar., 27	0.221	0.703	Sep., 7	6.87
	1968	0.343	1.903	Mar., 18	0.187	0.595	Aug., 5	10.18
	1969	0.360	1.444	Mar., 18	0.212	0.677	Jul., 20	6.81
	1970	0.323	0.949	Apr., 20	0.190	0.604	Jul., 7	4.99
	1971	0.331	0.960	Apr., 13	0.209	0.667	Aug., 7	4.59
	1972	0.368	2.311	Apr., 13	0.246	0.785	Jul., 8	9.39
	1973	0.377	2.495	Mar., 4	0.221	0.703	Aug., 17	11.29
	1974	0.391	2.974	Mar., 5	0.238	0.758	Aug., 11	12.50
	1975*	*	*	*	*	*	*	*
W-3	1967*	*	*	*	*	*	*	*
	1968	0.150	4.106	Feb., 2	0.009	0.039	Aug., 29	456.22
	1969	0.187	4.390	Jan., 24	0.012	0.050	Jul., 23	365.83
	1970	0.150	1.291	Mar., 23	0.011	0.047	Aug., 11	117.36
	1971	0.159	3.568	Apr., 2	0.003	0.012	Sep., 2	1189.33
	1972	0.238	4.446	Apr., 13	0.023	0.096	Sep., 22	193.30
	1973	0.209	2.311	Apr., 1	0.010	0.043	Sep., 9	231.10
	1974	0.192	3.512	Mar., 5	0.019	0.081	Sep., 21	184.84
	1975*	*	*	*	*	*	*	*
02HD009	1966*	*	*	*	*	*	*	*
	1967	0.892	6.712	Mar., 27	0.328	0.344	Sep., 13	20.46
	1968	0.872	0.742	Feb., 2	0.272	0.284	Jul., 30	35.82
	1969	0.886	5.664	Jan., 30	0.309	0.323	Jul., 23	18.33
	1970	0.796	3.313	Mar., 23	0.328	0.344	Aug., 18	10.10
	1971	0.810	7.476	Apr., 2	0.294	0.308	Aug., 20	25.43
	1972	1.014	11.441	Apr., 13	0.385	0.403	Aug., 1	29.72
	1973	1.045	12.914	Mar., 4	0.345	0.361	Aug., 16	37.43
	1974	0.943	10.620	Mar., 5	0.430	0.450	Aug., 26	24.70
	1975*	*	*	*	*	*	*	*

* indicates incomplete records

Table 26. Monthly, Annual and Long-Term Mean Surface Runoff as Measured at Various Stations in the Study Area for the Period 1968-1973

(All values in mm)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
B-2	1968	23.4	50.5	98.8	36.3	31.0	18.8	13.5	15.2	20.3	19.3	29.7	31.0	387.9
	1969	36.7	18.3	66.8	53.1	37.1	20.6	19.1	16.5	12.9	20.1	25.6	23.1	349.9
	1970	17.5	17.5	44.2	77.7	23.4	14.0	15.0	12.4	14.7	17.8	22.9	24.4	301.5
	1971	20.6	20.1	29.2	94.0	21.1	26.7	24.4	14.5	14.7	15.7	16.8	33.3	331.0
	1972	25.6	19.1	27.2	142.0	49.8	21.6	16.0	19.0	15.0	21.8	29.7	45.2	432.0
	1973	*	*	*	*	*	*	*	*	*	*	*	*	*
	Means	24.8	25.1	53.2	80.6	32.5	20.3	17.6	15.5	15.5	18.9	24.9	31.4	360.5
B-4	1968	26.4	50.0	84.5	40.3	40.4	27.6	22.5	26.9	29.5	29.4	40.1	39.8	457.4
	1969	50.5	31.2	71.2	62.0	44.6	28.6	31.7	30.0	23.9	28.3	34.9	32.9	469.8
	1970	21.3	29.9	63.0	71.9	30.0	19.5	24.5	21.3	24.0	28.2	32.4	33.2	399.2
	1971	29.7	32.3	39.1	109.5	26.7	30.8	26.9	22.2	23.8	24.9	27.1	37.8	430.8
	1972	27.4	24.8	34.6	136.3	38.6	30.5	27.4	30.7	27.1	35.3	36.0	42.8	491.5
	1973	25.1	33.6	87.8	60.1	40.1	26.0	21.0	24.6	23.1	27.5	30.6	29.4	428.9
	Means	30.1	33.6	63.4	80.0	36.7	27.2	25.7	25.9	25.2	28.9	33.5	35.9	446.3
S-1	1968	*	*	*	31.4	27.1	20.5	17.5	17.9	19.1	17.6	22.8	26.3	*
	1969	46.3	25.1	61.3	54.5	39.2	26.8	25.5	25.3	20.3	23.9	28.1	23.1	400.4
	1970	24.9	27.1	66.6	97.6	31.6	19.8	23.7	20.5	20.6	23.7	24.8	23.4	404.3
	1971	24.9	26.6	31.6	91.8	28.8	21.9	21.5	19.7	19.5	20.8	20.9	25.0	353.0
	1972	24.8	24.0	33.1	125.2	37.1	24.9	24.1	24.2	22.0	27.3	29.1	37.1	432.8
	1973	50.5	30.7	103.1	56.6	38.3	25.6	21.6	22.1	20.6	23.1	26.9	27.2	446.3
	Means	34.3	26.7	59.1	85.1	35.0	23.8	23.3	22.3	20.6	23.8	26.0	27.2	407.4

Table 26 (cont'd)

S-2	1968	27.7	44.4	86.0	36.8	36.6	24.1	16.3	19.8	22.9	23.6	33.8	29.0	401.0
	1969	50.0	26.2	69.3	54.1	39.9	27.4	24.6	31.7	15.7	21.6	31.2	24.9	416.6
	1970	17.5	24.4	57.9	61.2	30.0	17.5	20.1	16.3	19.3	24.4	28.4	26.2	343.1
	1971	22.1	25.9	38.5	95.0	25.9	24.1	20.6	16.0	18.3	19.6	22.1	30.7	358.6
	1972	24.1	22.6	40.6	148.8	34.8	23.6	21.8	23.4	19.3	28.7	32.0	38.3	458.2
	1973	46.0	36.1	109.2	61.2	38.6	23.9	15.5	17.5	14.2	19.8	27.7	25.4	435.1
	Means	31.2	29.9	66.9	76.2	34.3	23.4	19.8	20.8	18.3	22.9	29.2	29.1	402.1
S-3	1968	30.5	46.7	93.7	38.6	36.1	27.4	21.9	23.9	24.5	24.8	32.3	33.0	433.4
	1969	65.2	27.3	54.3	51.0	36.8	27.8	25.3	29.7	19.7	34.5	30.3	29.8	421.7
	1970	28.0	25.6	61.1	62.1	35.6	23.6	25.8	20.7	23.1	27.6	31.4	32.1	396.7
	1971	31.3	39.4	45.5	97.0	29.4	25.3	23.6	18.5	20.6	22.4	24.5	32.4	409.9
	1972	29.6	25.7	45.5	128.8	37.8	26.6	25.1	26.4	24.1	31.5	32.5	41.2	474.8
	1973	52.7	39.5	86.9	59.1	42.6	29.7	21.7	23.7	21.4	26.1	33.7	33.6	470.7
	Means	39.5	34.0	64.5	72.8	36.4	26.7	23.9	23.8	22.2	26.1	30.8	33.7	434.5
S-4	1968	9.1	43.9	91.4	24.4	18.3	8.1	3.3	3.6	4.1	6.3	17.2	15.0	244.7
	1969	96.8	21.1	24.9	50.8	25.6	10.2	7.4	16.5	4.1	7.6	16.3	22.1	303.4
	1970	11.9	31.0	57.7	46.0	16.5	15.7	6.1	2.5	3.6	8.9	15.2	18.0	233.2
	1971	8.4	103.9	95.0	53.8	8.1	6.1	4.6	3.5	4.3	5.6	6.3	16.0	315.7
	1972	9.4	9.6	106.4	108.2	15.0	6.9	6.3	8.6	5.1	10.0	20.0	55.5	361.0
	1973	48.5	43.0	112.5	58.6	21.0	9.0	4.0	3.6	2.9	5.6	10.9	14.4	334.0
	Means	30.7	42.1	81.3	57.0	17.4	9.3	5.3	6.4	4.0	7.3	14.3	23.5	298.7

Table 26 (cont'd)

Soper Creek	1968	*	*	*	*	*	*	8.4	11.9	12.2	12.9	22.6	23.4	*
02HD007	1969	101.3	30.7	57.1	57.4	35.6	23.4	17.3	21.6	12.2	15.0	25.4	27.4	419.4
	1970	16.8	35.3	80.5	55.6	26.7	14.0	13.5	11.2	12.7	15.5	23.4	27.4	332.6
	1971	17.0	51.8	61.0	87.4	16.8	14.7	11.2	9.4	11.2	12.7	16.3	30.7	340.2
	1972	29.7	16.3	44.7	145.3	24.9	16.8	15.0	14.2	12.9	23.1	31.2	48.0	422.1
	1973	48.5	40.1	110.0	64.8	39.9	*	*	*	*	*	*	*	*
	Means	41.2	33.5	59.6	75.6	26.0	17.2	14.2	14.1	14.1	16.65	24.1	33.4	367.8
W-1	1968	26.7	26.7	38.6	27.9	27.7	26.4	25.6	26.2	26.7	29.7	31.2	30.2	343.7
	1969	30.7	27.7	38.6	34.0	28.2	28.2	30.7	28.7	24.1	30.0	30.7	28.2	359.9
	1970	27.4	24.6	28.2	36.3	29.5	26.7	28.7	26.2	26.4	31.2	30.5	29.2	344.7
	1971	27.7	26.7	30.5	36.6	24.1	22.6	24.6	23.6	24.6	27.7	26.9	29.5	325.1
	1972	25.1	23.1	26.1	40.4	28.4	26.4	24.9	25.1	24.6	28.2	27.4	26.9	326.9
	1973	27.4	24.4	48.8	31.5	30.2	26.4	24.9	27.7	25.9	32.8	35.6	30.7	366.3
	Means	27.5	25.5	35.1	34.4	28.0	26.1	26.7	26.3	25.4	29.9	30.4	29.1	344.4
W-2	1968	29.6	35.6	63.8	36.8	35.2	28.7	21.9	25.5	25.6	28.7	34.7	33.5	399.6
	1969	40.5	25.7	50.0	48.2	33.8	27.7	29.3	33.3	25.1	30.1	35.9	35.7	415.3
	1970	27.3	22.6	33.5	50.2	33.5	25.0	28.6	24.5	25.9	33.5	38.6	34.90	378.1
	1971	29.0	30.3	35.2	56.8	34.9	29.9	27.3	23.3	25.6	29.2	29.8	36.0	387.3
	1972	31.7	27.0	32.9	69.9	38.8	31.5	30.0	32.8	28.3	34.3	36.6	39.8	433.6
	1973	40.3	36.4	67.9	43.6	38.8	29.8	25.0	27.7	25.2	31.1	37.3	34.8	437.9
	Means	33.1	29.6	47.2	50.9	35.8	28.8	27.0	27.8	25.9	31.1	35.5	35.8	408.6
W-3	1968	10.9	41.1	82.8	24.6	21.1	7.1	2.3	2.0	2.5	3.6	14.2	13.7	226.1
	1969	59.2	18.5	47.0	50.3	26.7	13.7	13.0	11.7	2.3	5.3	18.0	18.3	284.0
	1970	8.1	11.7	59.9	59.9	24.5	8.9	7.9	2.5	2.5	8.6	16.8	16.0	228.3
	1971	9.1	15.7	48.5	104.1	13.7	9.6	4.8	2.0	2.8	5.1	6.9	18.8	241.3
	1972	14.7	14.5	40.1	136.9	23.1	9.9	10.9	18.3	7.6	17.3	29.5	39.1	361.9
	1973	50.3	23.6	81.8	59.7	38.6	15.5	3.9	3.1	2.8	6.2	15.8	14.5	315.8
	Means	25.4	20.8	60.0	72.6	24.6	22.3	7.1	6.6	3.4	7.7	16.9	20.1	276.2

Table 26 (cont'd)

Wilmot	1968	32.0	48.8	82.3	30.7	27.6	16.5	11.2	12.4	13.2	14.0	23.4	27.7	339.8
Creek	1969	56.6	24.4	47.5	45.2	29.2	19.8	19.0	21.3	12.4	16.8	24.9	26.9	344.0
02HD009	1970	17.8	26.2	49.3	50.8	28.4	17.5	17.5	12.7	14.0	19.6	24.9	30.2	308.9
	1971	20.8	22.6	41.9	77.7	23.4	19.0	15.7	13.5	15.3	17.8	19.0	29.7	316.3
	1972	32.5	24.9	37.6	102.9	28.2	19.0	19.0	22.6	17.0	23.7	28.4	37.7	393.5
	1973	40.4	34.2	91.9	51.5	37.2	23.2	14.6	15.5	14.3	22.2	29.2	24.4	398.6
	Means	33.3	30.2	58.4	59.8	29.0	19.2	16.2	16.3	14.3	19.0	24.9	29.4	350.2

* indicates missing records

Table 27. Number of Obserrvations, Sample Means, Standard Deviations, Standard Errors of Means, and the Estimated Population Means at 95% Confidence Level of Ground Water Level Elevations in Shallow Observation Wells.

Well No.	No. of Observations	Sample Mean (m)	Standard Deviation (m)	Standard Error of Sample Mean (m)	Estimated Population Mean at 95% Confidence Level (m)
WS-14	44	232.07	1.08	0.16	230.07 ± 0.33
WS-16	26	194.21	0.26	0.05	194.21 ± 0.11
WS-17	42	194.35	0.82	0.13	194.35 ± 0.26
WS-19	39	193.61	0.38	0.06	193.61 ± 0.13
WS-20	38	248.89	1.18	0.19	248.89 ± 0.39
WS-23	38	193.00	0.64	0.10	193.00 ± 0.21
WS-24	38	255.17	0.39	0.63	255.17 ± 0.13
WS-25	42	265.37	1.82	0.28	265.37 ± 0.57
WS-26	26	255.46	0.63	0.12	255.46 ± 0.26
WS-27	33	214.40	0.84	0.15	214.40 ± 0.30
WS-28	39	188.09	2.03	0.33	188.11 ± 0.66
WS-35	41	117.28	0.79	0.12	177.28 ± 0.25
WS-38	41	132.87	0.76	0.12	132.87 ± 0.24
WS-39	40	155.84	0.75	0.12	155.84 ± 0.24
WS-41	41	104.29	0.93	0.15	104.29 ± 0.30
WS-42	39	105.67	1.06	0.17	105.67 ± 0.35

Table 28. Linear Regression Equations Expressing the Statistical Association Between Ground Water Level Elevations in Well W-5-B and Corresponding Elevations in Shallow Observation Wells.

Well No.	No. of Observations	Regression Equation	Coefficient of Correlation	Standard Error of Estimate of X on Y (m)
WS-14	44	Y = 1.28 X - 65.41	0.86	0.54
WS-16	26	Y = 0.21 X - 144.29	0.61	0.21
WS-17	42	Y = 0.71 X - 29.02	0.65	0.63
WS-19	39	Y = 0.34 X - 115.35	0.67	0.29
WS-20	38	Y = 1.33 X - 60.51	0.88	0.57
WS-23	38	Y = 0.60 X - 53.58	0.66	0.48
WS-24	38	Y = 0.43 X - 154.85	0.76	0.25
WS-25	42	Y = 1.72 X - 135.56	0.71	1.28
WS-26	26	Y = 0.52 X - 134.59	0.54	0.53
WS-27	33	Y = 1.03 X - 25.71	0.94	0.28
WS-28	39	Y = 2.47 X - 385.58	0.85	1.08
WS-35	41	Y = 0.73 X - 51.75	0.65	0.60
WS-38	41	Y = 0.76 X - 44.27	0.70	0.54
WS-39	40	Y = 0.59 X - 16.97	0.54	0.63
WS-41	41	Y = 1.04 X - 138.43	0.79	0.57
WS-42	39	Y = 1.04 X - 136.51	0.71	0.53

X - Represents ground water elevation in well W-5-B.
Y - Represents ground water elevation in a shallow observation well.

Table 29. Estimates of Monthly and Annual Baseflows, their Long Term Means and Ratios of Annual Baseflow to Annual Runoff and Precipitation for Various Basins and Sub-Basins in the Study Area.

(All values in mm unless indicated)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Baseflow as % of total runoff	Baseflow as % of precip.
B-2	1968	17.8	23.6	38.6	30.2	22.1	15.7	12.7	10.7	10.5	9.8	20.8	25.9	238.2	61.4	24.0
	1969	19.3	16.3	22.9	35.0	27.9	18.3	14.2	13.2	11.7	10.8	19.8	19.8	229.2	65.5	29.7
	1970	16.3	13.5	24.1	42.4	20.8	13.2	12.2	11.7	10.7	10.2	9.5	20.8	205.4	68.2	25.9
	1971	19.8	16.3	24.1	39.6	19.3	15.2	14.5	12.7	11.7	10.4	12.7	21.8	218.1	65.9	28.3
	1972	20.6	17.8	22.1	51.0	39.4	16.8	14.5	13.0	11.9	15.9	20.3	24.1	267.4	61.9	30.5
	Means	18.8	17.9	26.4	33.6	25.9	15.8	13.6	12.3	11.3	11.4	16.6	22.5	231.7	64.3	27.6
B-4	1968	20.3	26.9	41.1	35.8	29.5	25.1	21.8	20.6	19.1	17.7	30.2	36.1	324.4	70.9	35.9
	1969	31.2	23.3	36.1	41.7	33.3	25.9	23.4	21.9	18.8	15.4	19.0	25.0	315.0	67.0	37.4
	1970	17.7	15.8	25.4	43.2	24.9	17.8	16.6	15.1	14.1	14.0	23.4	20.0	248.0	62.1	31.2
	1971	21.7	20.5	25.6	44.2	24.6	22.6	20.6	20.3	18.6	16.1	14.4	20.5	269.7	62.6	32.5
	1972	25.6	19.4	23.2	74.6	33.8	25.6	24.1	23.1	21.4	20.1	30.3	35.4	356.6	72.5	36.5
	1973	19.8	22.7	52.5	41.8	30.7	24.1	19.2	17.5	15.3	13.2	25.9	24.7	307.4	71.7	33.0
	Means	22.7	21.4	34.0	46.9	29.5	23.5	20.9	19.7	17.9	16.1	23.9	26.9	303.5	67.8	34.4
S-1	1968	---	---	---	26.9	21.6	18.5	15.6	15.0	14.3	13.0	17.0	21.1	-----	---	---
	1969	20.8	21.8	25.4	37.1	30.0	23.1	20.8	20.1	18.0	16.5	23.1	19.0	275.7	68.8	31.0
	1970	20.3	24.4	32.3	59.7	26.4	18.3	17.8	16.5	15.5	15.1	20.1	21.3	287.7	71.2	35.9
	1971	20.1	22.1	27.2	46.5	23.6	17.8	16.8	16.0	15.0	14.5	13.0	21.1	253.7	71.8	29.1
	1972	22.6	22.1	26.2	47.2	31.5	21.6	21.0	20.0	19.0	18.0	26.2	34.8	310.2	71.6	29.1
	1973	32.5	20.1	43.4	37.1	30.7	21.6	20.3	19.3	18.6	17.6	22.2	23.1	306.5	68.7	33.6
	Means	---	---	---	42.4	27.3	20.2	18.7	17.8	16.7	15.8	20.3	23.4	-----	---	---

Table 29 (con't)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Baseflow as % of total runoff	Baseflow as % of precip.
S-2	1968	23.4	25.4	39.4	30.5	26.9	20.6	15.2	14.0	12.3	11.1	13.9	24.8	257.5	64.2	31.7
	1969	23.6	21.3	25.5	38.1	30.5	23.1	18.5	16.6	15.5	14.0	24.1	21.1	271.9	65.3	33.5
	1970	15.7	20.3	31.5	42.7	24.6	16.3	16.0	15.2	14.0	13.3	24.4	22.9	256.9	74.9	32.7
	1971	19.8	21.1	30.7	46.5	24.9	18.5	16.3	13.7	12.0	11.3	10.6	22.3	247.7	69.0	28.2
	1972	18.8	18.5	26.9	44.4	29.7	19.0	18.0	17.8	15.7	14.6	25.9	26.7	276.0	60.2	26.1
	1973	27.4	20.3	39.1	38.1	29.7	20.1	14.7	14.0	13.0	12.6	24.1	21.2	274.3	63.0	29.0
	Means	21.4	21.1	32.2	40.0	27.7	19.6	16.4	15.2	13.7	12.8	20.5	23.1	264.1	66.1	25.2
S-3	1968	27.7	27.9	38.9	34.5	28.7	24.4	20.6	19.3	18.8	17.3	24.1	29.2	311.4	71.8	37.4
	1969	28.4	24.9	30.7	35.0	27.9	23.9	21.6	18.8	17.5	16.5	24.1	25.1	294.4	69.8	34.8
	1970	25.1	23.1	29.7	43.2	30.5	22.6	21.3	19.8	17.8	15.9	25.6	22.9	297.5	74.9	37.8
	1971	25.9	24.1	34.8	50.2	24.3	19.6	19.0	17.8	16.8	15.3	14.3	24.9	287.0	70.0	34.6
	1972	22.1	21.3	25.9	55.4	32.3	22.1	20.3	19.1	18.3	17.4	27.2	29.5	310.9	65.5	29.7
	1973	30.7	24.6	36.9	34.2	35.1	24.3	19.4	18.7	17.9	16.7	24.8	26.1	309.4	65.7	35.6
	Means	26.6	24.3	32.8	42.1	29.8	22.8	20.4	18.9	17.8	16.5	23.3	26.3	301.8	69.6	35.0
S-4	1968	6.3	10.2	14.6	18.0	10.7	6.3	2.8	2.5	2.3	2.0	12.0	8.9	96.6	39.5	12.8
	1969	17.1	16.0	11.2	22.1	15.0	7.4	6.3	5.3	3.5	3.0	11.1	13.1	131.1	43.2	16.7
	1970	5.4	8.6	12.8	21.8	9.1	8.3	4.2	2.1	2.0	1.8	9.4	12.8	98.3	42.1	12.8
	1971	6.9	21.6	35.4	16.2	7.6	4.1	3.0	2.3	2.0	1.8	1.8	9.1	111.8	35.4	14.9
	1972	6.6	7.8	22.7	25.4	10.9	6.1	5.1	4.6	3.3	3.1	13.4	20.3	129.3	35.8	13.7
	1973	17.4	20.5	27.5	13.7	12.8	7.3	3.1	2.2	2.0	1.9	8.5	9.0	125.9	37.7	16.1
	Means	9.9	14.1	20.7	19.5	11.7	6.6	4.1	3.2	2.5	2.3	9.4	12.2	115.5	38.9	14.5

Table 29 (con't)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Baseflow as % of total runoff	Baseflow as % of precip.
02HD007	1969	53.2	24.6	33.6	35.5	23.3	18.3	14.6	13.3	12.0	11.5	18.9	21.8	280.7	66.9	34.7
	1970	15.8	19.7	40.7	34.9	19.7	11.3	11.1	10.3	9.9	9.5	17.0	21.9	221.8	66.7	28.2
	1971	11.7	19.3	40.4	40.9	15.5	9.7	9.0	8.0	7.1	5.9	5.0	21.3	193.8	57.0	23.9
	1972	22.1	13.5	16.5	50.3	18.8	12.7	11.2	9.9	9.4	8.3	23.6	26.0	222.3	52.7	21.8
	Means	25.7	19.3	32.7	40.4	19.3	13.0	11.5	10.4	9.6	8.8	16.1	22.7	229.6	60.8	27.1
W-1	1968	26.1	24.7	28.9	26.9	26.2	25.7	25.4	25.2	24.8	24.2	28.7	29.5	316.3	92.0	35.6
	1969	29.5	27.2	31.5	30.0	27.4	26.9	26.4	26.2	23.1	22.1	28.7	27.4	326.4	90.7	36.8
	1970	26.4	24.2	26.5	31.8	28.6	25.8	25.7	25.2	25.0	24.2	23.0	26.2	312.6	90.6	38.8
	1971	26.9	25.6	29.7	31.5	23.6	22.5	22.1	22.0	21.6	21.0	20.0	26.9	293.4	90.2	33.7
	1972	24.0	22.4	24.9	29.4	26.8	24.1	23.7	23.6	23.3	26.7	26.4	25.2	300.5	91.9	28.2
	1973	25.6	22.6	33.1	28.7	28.2	26.1	24.7	24.1	24.1	23.9	33.1	27.1	321.3	87.7	35.3
	Means	26.4	24.4	29.1	29.7	26.8	25.2	24.7	24.4	23.7	23.7	26.7	27.1	311.7	90.5	34.7
W-2	1968	26.2	25.9	32.9	35.0	29.6	26.6	21.3	20.7	20.0	19.4	28.7	31.2	317.5	79.4	35.8
	1969	29.9	24.7	28.6	38.0	31.0	25.5	23.5	22.3	20.9	20.5	32.0	33.6	330.5	79.6	37.3
	1970	25.5	20.9	26.2	34.5	31.1	23.4	23.0	22.2	20.9	19.4	19.0	31.8	297.9	78.8	36.9
	1971	27.1	26.6	33.6	41.7	33.2	27.6	24.3	21.6	20.8	20.6	19.6	31.1	328.8	84.9	37.8
	1972	30.8	26.5	30.2	42.7	35.4	26.2	25.5	23.9	21.3	20.8	31.3	35.9	350.5	80.8	32.9
	1973	33.7	31.3	39.6	37.2	34.8	27.1	23.6	22.9	21.7	20.6	34.5	31.7	358.7	81.9	39.4
	Means	28.9	25.9	31.8	38.2	32.5	26.1	23.5	22.3	20.9	20.2	27.5	32.5	330.6	80.9	36.7

Table 29 (con't)

Basin	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Baseflow as % of total runoff	Baseflow as % of precip.
W-3	1968	8.2	9.4	10.4	13.3	6.5	3.4	1.9	1.3	1.1	1.0	1.0	4.2	61.7	27.3	9.5
	1969	3.6	6.9	10.5	17.4	12.7	6.1	1.9	1.5	1.2	1.1	3.8	9.4	77.1	27.1	9.4
	1970	7.4	8.2	9.2	14.1	12.2	4.4	3.7	1.8	1.5	1.4	1.3	10.7	75.9	33.2	9.5
	1971	8.6	8.1	15.8	24.6	11.1	3.8	2.3	1.3	1.0	0.9	0.6	7.0	86.0	35.6	11.6
	1972	7.8	7.7	8.1	26.8	12.9	4.6	4.0	3.7	3.7	3.3	2.7	20.8	106.1	29.3	11.4
	1973	13.2	7.9	20.5	20.9	9.0	8.6	2.7	2.1	2.0	1.2	1.1	6.0	95.2	30.1	12.2
	Means	8.1	8.0	12.4	19.5	10.7	5.1	2.7	1.9	1.7	1.5	1.7	9.7	83.7	30.4	10.6
02HD009	1968	17.8	21.1	23.1	24.4	19.6	14.0	10.7	10.4	9.4	9.2	16.3	19.8	195.8	57.6	25.3
	1969	18.3	18.5	19.3	24.1	19.3	15.2	12.7	11.4	10.2	9.0	18.5	20.1	196.6	57.1	23.2
	1970	16.0	14.2	16.5	19.0	20.3	14.5	14.0	11.7	10.2	9.2	7.8	8.3	161.7	52.3	19.6
	1971	15.0	15.5	28.7	28.2	20.3	14.0	13.2	10.7	9.2	8.7	8.5	18.0	190.0	60.0	23.7
	1972	18.8	18.8	19.6	22.1	19.0	14.0	13.0	12.2	10.7	9.3	10.5	22.3	190.3	48.4	19.0
	1973	18.1	19.7	25.3	19.2	18.0	16.1	13.0	12.4	12.1	10.3	9.7	18.2	192.1	48.2	22.9
	Means	17.3	17.9	22.1	22.8	19.4	14.6	12.8	11.5	10.3	9.3	11.9	17.8	187.7	53.9	22.3

Table 30. A Comparison between Monthly and Annual Ground Water Recharge as Estimated by the Geohydrologic Method (G) and the Hydro-meteorologic Method (H) for the Wilmot Creek Basin and Sub-Basins. (All values in mm).

Basin	Year	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-1	1967	G	--	--	--	--	--	--	--	--	--	32.8	68.6	48.8	----
		H	--	--	--	--	--	--	--	--	--	--	--	--	----
	1968	G	22.6	22.6	54.5	20.6	14.2	1.8	0.0	5.6	11.6	15.4	45.9	55.9	270.7
		H	23.8	50.1	138.4	0.0	29.5	0.0	0.0	0.0	0.0	0.0	4.6	49.1	295.5
	1969	G	43.2	19.1	55.4	65.5	34.5	13.2	9.4	1.5	2.0	16.2	45.2	36.6	341.8
		H	107.3	10.7	66.1	61.0	19.8	0.0	0.0	0.0	0.0	0.0	42.3	43.7	350.9
	1970	G	21.8	18.5	64.8	71.1	20.5	0.0	3.8	0.0	6.1	19.1	49.0	20.8	295.5
		H	15.5	16.4	127.1	144.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	306.5
	1971	G	7.4	71.4	39.9	97.0	4.3	0.0	0.0	0.0	8.1	18.8	43.7	43.7	334.3
		H	7.3	76.6	39.8	210.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	350.4
	1972	G	43.7	19.6	44.2	103.4	6.8	0.0	6.4	16.2	13.2	33.0	60.2	40.6	387.3
		H	24.3	27.7	65.6	217.4	0.0	0.0	0.0	0.0	0.0	32.9	66.6	87.2	521.7
	1973	G	37.3	6.1	67.1	61.7	11.7	0.0	0.0	0.0	3.3	--	--	--	----
		H	66.3	32.2	119.7	60.2	30.7	0.0	0.0	0.0	0.0	0.0	12.2	42.9	365.2
W-2	1967	G	--	--	--	--	--	--	--	--	--	31.5	57.1	45.9	----
		H	--	--	--	--	--	--	--	--	--	--	--	--	----
	1968	G	24.1	24.1	48.8	31.0	22.3	11.9	0.0	9.7	13.7	18.5	39.4	47.5	291.0
		H	31.0	42.4	117.2	0.0	24.6	0.0	0.0	0.0	0.0	0.0	18.0	47.5	280.7

Table 30 (cont'd)

Basin	Year	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	1969	G	38.3	19.5	43.4	60.2	36.1	17.3	11.7	11.2	11.9	21.1	42.2	39.1	352.0
		H	97.9	10.2	51.8	54.8	17.8	0.0	0.0	0.0	0.0	0.0	58.1	42.4	333.0
	1970	G	22.6	17.5	49.8	58.7	25.9	3.5	8.4	6.1	11.9	24.4	46.5	43.7	319.0
		H	14.7	15.1	121.5	133.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	297.3
	1971	G	25.4	35.8	48.0	85.1	10.2	9.1	5.1	6.8	14.2	22.6	40.9	40.9	344.1
		H	6.2	74.0	39.0	200.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.8	343.5
	1972	G	40.9	24.6	42.2	88.4	22.9	8.1	16.7	22.3	19.3	34.7	55.1	45.5	420.7
		H	24.5	27.9	64.1	201.2	0.0	0.0	0.0	0.0	0.0	0.0	39.6	85.0	442.3
	1973	G	41.1	21.0	60.4	57.4	24.1	11.4	0.0	6.3	10.2	--	--	--	----
		H	61.5	29.9	107.1	56.6	28.7	0.0	0.0	0.0	0.0	0.0	22.8	43.4	350.0
W-3	1967	G	--	--	--	--	--	--	--	--	--	10.2	14.2	10.9	---
		H	--	--	--	--	--	--	--	--	--	--	--	--	---
	1968	G	8.6	8.6	11.9	12.9	5.8	2.0	0.0	0.0	0.0	1.8	3.8	5.6	61.0
		H	27.0	17.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	53.4
	1969	G	4.3	6.4	11.7	19.3	13.2	5.3	1.0	1.8	0.7	2.3	9.9	9.9	85.8
		H	10.7	3.7	0.5	27.9	5.8	0.0	0.0	0.0	0.0	0.0	4.8	35.3	88.7
	1970	G	7.1	7.9	11.4	16.5	11.7	2.5	2.5	0.0	0.7	3.3	9.9	11.7	85.2
		H	17.6	27.1	81.6	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.7	154.3
	1971	G	7.9	8.9	17.0	28.7	8.9	2.0	0.0	0.0	0.0	2.5	7.1	7.1	90.1
		H	9.0	18.2	21.9	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.2	95.3

Table 30 (cont'd)

Basin	Year	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-3	1972	G	7.1	7.6	9.1	20.8	11.7	1.8	3.0	3.3	3.3	8.6	18.8	21.8	116.9
		H	34.0	7.1	39.3	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.3	164.8
	1973	G	13.9	6.8	27.4	27.9	18.0	7.1	0.0	0.0	1.0	--	--	--	---
		H	6.0	8.5	32.8	8.7	5.4	0.0	0.0	0.0	0.0	0.0	0.0	16.2	77.6
02HD009	1967	G	--	--	--	--	--	--	--	--	--	17.3	31.7	26.7	---
		H	--	--	--	--	--	--	--	--	--	--	--	--	---
	1968	G	18.3	18.3	31.2	21.8	16.0	7.1	0.0	4.1	6.6	10.2	21.1	27.4	182.1
		H	17.3	30.1	47.6	0.0	5.6	0.0	0.0	0.0	0.0	0.0	23.0	39.8	163.4
	1969	G	22.4	11.7	25.9	38.1	22.9	11.2	5.6	5.3	5.8	11.4	25.1	23.1	208.5
		H	55.8	5.0	21.3	41.0	9.7	0.0	0.0	0.0	0.0	0.0	32.3	55.2	220.3
	1970	G	14.5	12.7	30.0	35.6	17.8	3.0	5.6	3.3	5.8	13.5	25.2	24.4	191.4
		H	15.6	13.1	67.3	63.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	161.6
	1971	G	15.0	20.6	32.0	52.6	9.1	5.1	2.5	3.2	7.9	12.9	22.9	22.9	206.7
		H	5.7	44.6	36.5	115.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	218.5
	1972	G	22.9	15.2	25.4	53.3	17.0	5.6	8.9	11.7	10.2	15.8	34.3	47.6	267.9
		H	19.0	17.3	56.4	92.8	0.0	0.0	0.0	0.0	0.0	0.0	9.7	83.1	278.3
	1973	G	23.4	13.1	34.2	30.9	10.4	5.1	3.2	3.4	5.7	--	--	--	---
		H	33.6	13.6	51.4	23.8	14.6	0.0	0.0	0.0	0.0	0.0	0.0	34.5	171.5

Table 31. Monthly and Annual Hydrologic Budgets for Various Basins and Sub-basins in the Bowmanville, Soper and Wilmot Creeks (all values in mm)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
B-2	1968	Precipitation	81.0	62.7	79.8	30.7	100.1	100.1	40.4	110.7	108.5	53.1	143.5	80.8	991.4
		Rain and melt	-	-	-	-							-	-	-
		Surface runoff	23.4	50.5	98.8	36.3	31.0	18.8	13.5	15.2	20.3	19.3	29.7	31.0	387.9
		Ground water runoff	17.8	23.6	38.6	30.2	22.1	15.7	12.7	10.7	10.5	9.8	20.8	25.9	238.2
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	125.7	111.0	86.4	45.0	7.6	0.0	583.9
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-
	1969	Precipitation	77.0	20.3	34.3	95.5	95.8	65.5	116.1	59.9	7.4	52.3	120.4	26.9	771.4
		Rain and melt	-	-	-	-							102.6	4.1	-
		Surface runoff	36.7	18.3	66.8	53.1	37.1	20.6	19.1	16.5	12.9	20.1	25.6	23.1	349.9
		Ground water runoff	19.3	16.3	22.9	35.0	27.9	18.3	14.2	13.2	11.7	10.8	19.8	19.8	229.2
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.0	35.5	67.3	98.5	122.7	88.6	18.8	37.6	12.9	0.0	481.7
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-
	1970	Precipitation	54.9	68.3	46.0	81.5	48.3	46.0	88.1	52.6	88.1	94.7	74.9	50.8	794.2
		Rain and melt	6.1	19.6	55.9	209.8							74.9	15.2	799.3
		Surface runoff	17.5	17.5	44.2	77.7	23.4	14.0	15.0	12.4	14.7	17.8	22.9	24.4	301.5
		Ground water runoff	16.3	13.5	24.1	42.4	20.8	13.2	12.2	11.7	10.7	10.2	9.5	20.8	205.4
		Ground water recharge	4.9	15.6	35.8	140.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	203.9
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	94.5	94.5	68.7	76.2	47.0	13.5	0.0	499.3
		Change in ground water storage	-11.4	+2.1	+11.7	+97.6	-20.8	-13.2	-12.2	-11.7	-10.7	-10.2	-9.5	-13.2	-1.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-24.7	-49.3	-9.2	-16.8	+7.9	+40.1	+48.0	+4.0	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
B-2	1971	Precipitation	46.0	52.8	32.0	36.1	31.0	154.9	97.8	58.7	65.5	38.1	55.4	101.9	770.1
		Rain and melt	10.0	17.0	31.2	144.2							45.0	95.8	789.2
		Surface runoff	20.6	20.1	29.2	94.0	21.1	26.7	24.4	14.5	14.7	15.7	16.8	33.3	331.0
		Ground water runoff	19.8	16.3	24.1	39.6	19.3	15.2	14.5	12.7	11.7	10.4	12.7	21.8	218.1
		Ground water recharge	9.2	13.2	26.1	68.7	0.0	12.7	0.0	0.0	0.0	0.0	8.6	84.3	222.8
		Actual evapotranspiration	0.0	0.0	0.0	21.1	56.3	103.6	92.8	66.9	68.8	41.4	2.5	0.0	453.5
		Change in ground water storage	-10.6	-3.1	+2.0	+29.1	-19.3	-2.5	-14.5	-12.7	-11.7	-10.4	-4.1	+62.5	+4.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-27.1	+27.1	-4.9	-10.0	-6.3	-8.6	+29.8	0.0	0.0
	1972	Precipitation	46.7	74.2	56.4	42.9	56.6	102.4	52.3	111.0	71.9	93.5	61.2	106.4	876.6
		Rain and melt	19.6	11.0	47.2	156.6							61.2	93.7	877.0
		Surface runoff	25.6	19.1	27.2	142.0	49.8	21.6	16.0	19.0	15.0	21.8	29.7	45.2	432.0
		Ground water runoff	20.6	17.8	22.1	51.0	39.4	16.8	14.5	13.0	11.9	15.9	20.3	24.1	267.4
		Ground water recharge	14.6	9.7	42.1	53.9	0.0	0.0	0.0	0.0	0.0	29.9	49.5	72.6	272.3
		Actual evapotranspiration	0.0	0.0	0.0	11.7	79.5	87.8	80.6	87.7	63.1	27.4	2.3	0.0	440.1
		Change in ground water storage	-6.0	-8.1	+20.0	+2.9	-39.4	-16.8	-14.5	-13.0	-11.9	+14.0	+29.2	+48.5	+4.9
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-33.3	+9.8	-29.8	+17.3	+5.7	+30.3	0.0	0.0	0.0
B-4	1968	Precipitation	70.4	54.1	70.4	28.4	105.2	80.5	33.0	100.3	98.0	54.9	128.5	80.8	904.5
		Rain and melt	-	-	-	-							-	-	-
		Surface runoff	26.4	50.0	84.5	40.3	40.4	27.6	22.5	26.9	29.5	29.4	40.1	39.8	457.4
		Ground water runoff	20.3	26.9	41.1	35.8	29.5	25.1	21.8	20.6	19.1	17.7	30.2	36.1	324.4
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	44.7	101.6	86.4	45.0	7.6	0.0	493.8
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
B-4	1969	Precipitation	73.7	18.8	36.3	93.7	91.9	69.3	113.5	98.4	8.9	60.2	109.0	68.4	842.1
		Rain and melt	-	-	-	-							93.4	40.4	-
		Surface runoff	50.5	31.2	71.2	62.0	44.6	28.6	31.7	30.0	23.9	28.3	34.9	32.9	469.8
		Ground water runoff	31.2	23.3	36.1	41.7	33.3	25.9	23.4	21.9	18.8	15.4	19.0	25.0	315.0
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	115.1	79.5	16.5	37.6	12.9	0.0	463.0
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-
	1970	Precipitation	53.3	49.8	60.2	79.5	56.1	43.2	93.2	42.7	81.8	98.8	71.6	64.5	794.8
		Rain and melt	12.6	21.7	93.9	155.9								25.7	797.2
		Surface runoff	21.3	29.9	63.0	71.9	30.0	19.5	24.5	21.3	24.0	28.2	32.4	33.2	399.2
		Ground water runoff	17.7	15.8	25.4	43.2	24.9	17.8	16.6	15.1	14.1	14.0	23.4	20.0	248.0
		Ground water recharge	9.0	7.6	56.3	92.7	0.0	0.0	0.0	0.0	0.0	0.0	36.1	12.5	214.2
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	50.8	87.5	51.8	76.2	47.0	13.5	0.0	431.8
		Change in ground water storage	-8.7	-8.2	+30.9	+49.5	-24.9	-17.8	-16.6	-15.1	-14.1	-14.0	+12.7	-7.5	-33.8
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-19.4	-9.3	-2.2	-15.3	-4.4	+37.6	+13.0	0.0	0.0
B-4	1971	Precipitation	58.9	79.8	55.9	34.3	30.5	143.5	92.7	59.4	66.8	42.9	58.4	107.2	830.3
		Rain and melt	9.0	47.2	50.9	164.4							48.3	94.4	850.0
		Surface runoff	29.7	32.3	39.1	109.5	26.7	30.8	26.9	22.2	23.8	24.9	27.1	37.8	430.8
		Ground water runoff	21.7	20.5	25.6	44.2	24.6	22.6	20.6	20.3	18.6	26.1	14.4	20.5	269.7
		Ground water recharge	1.0	35.4	37.4	78.0	0.0	23.8	13.9	0.0	0.0	0.0	6.7	77.1	273.3
		Actual evapotranspiration	0.0	0.0	0.0	21.1	56.3	83.6	72.8	65.8	69.1	44.7	2.5	0.0	415.6
		Change in ground water storage	-20.7	+14.9	+11.8	+33.8	-24.6	+1.2	-6.7	-20.3	-18.6	-16.1	-7.7	+56.6	+3.6
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-27.9	+27.9	0.0	-8.3	-7.5	-10.6	+26.4	0.0	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
B-4	1972	Precipitation	51.8	83.6	87.4	59.4	54.4	93.0	73.2	117.1	79.8	96.3	66.5	113.8	976.1
		Rain and melt	17.8	17.4	67.4	201.2							66.5	92.8	976.9
		Surface runoff	27.4	24.8	34.6	136.3	38.6	30.5	27.4	30.7	27.1	35.3	36.0	42.8	491.5
		Ground water runoff	25.6	19.4	23.2	74.6	33.8	25.6	24.1	23.1	21.4	20.1	30.3	35.4	356.6
		Ground water recharge	16.0	12.0	56.0	123.8	0.0	0.0	0.0	0.0	0.0	14.7	58.5	85.4	366.4
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	93.5	79.5	97.7	80.0	27.4	2.3	0.0	475.6
		Change in ground water storage	-9.67	-7.4	+32.8	+49.2	-33.8	-25.6	-24.1	-23.1	-21.4	-5.4	+28.2	+50.0	+9.8
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-29.9	-5.4	-9.6	+11.8	-5.9	+39.0	0.0	0.0	0.0
	1973	Precipitation	38.1	36.6	117.9	87.1	117.1	67.8	48.3	69.6	50.0	117.6	107.6	73.2	930.5
		Rain and melt	57.5	23.7	132.4								107.2	43.3	921.6
		Surface runoff	25.1	33.6	87.8	60.1	40.1	26.0	21.0	24.6	23.1	27.5	30.6	29.4	428.9
		Ground water runoff	19.8	22.7	52.5	41.8	30.7	24.1	19.2	17.5	15.3	13.2	25.9	24.7	307.4
		Ground water recharge	52.2	12.8	83.4	40.1	46.2	0.0	0.0	0.0	0.0	0.0	73.8	38.6	347.1
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	57.1	75.4	52.6	44.2	9.6	0.0	453.0
		Change in ground water storage	+32.4	-9.9	+30.9	-1.7	+15.5	-24.1	-19.2	-17.5	-15.3	-13.2	+47.9	+13.9	+39.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-44.3	-10.6	-12.9	-10.4	+59.1	+19.1	0.0	0.0
S-1	1968	Precipitation	70.1	70.9	66.5	29.2	106.9	56.9	12.2	94.2	82.6	60.4	126.5	111.0	887.5
		Rain and melt	24.4	52.1	148.3								126.0	49.8	843.0
		Surface runoff	-	-	-	31.4	27.1	20.5	17.5	17.9	19.1	17.6	22.8	26.3	-
		Ground water runoff	-	-	-	26.9	21.6	18.5	15.6	15.0	14.3	13.0	17.0	21.1	-
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	24.9	96.0	83.1	45.0	7.6	0.0	464.8
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-1	1969	Precipitation	65.0	32.0	38.1	97.0	87.9	74.2	119.4	117.6	8.6	59.2	109.0	78.7	886.7
		Rain and melt	108.5	11.2	73.2	100.6							90.7	44.5	895.5
		Surface runoff	46.3	25.1	61.3	54.5	39.2	26.8	25.5	25.3	20.3	23.9	28.1	23.1	400.4
		Ground water runoff	20.8	21.8	25.4	37.1	30.0	23.1	20.8	20.1	18.0	16.5	23.1	19.0	275.7
		Ground water recharge	83.0	7.9	37.3	47.6	11.4	0.0	0.0	0.0	0.0	0.0	56.5	40.4	284.1
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	110.4	108.1	17.3	37.6	12.9	0.0	486.7
		Change in ground water storage	+62.2	-13.9	+11.9	+10.5	-18.6	-23.1	-20.8	-20.1	-18.0	-16.5	+33.4	+21.4	+8.4
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-28.1	+4.3	+4.3	-11.0	+14.2	+16.2	0.0	0.0
	1970	Precipitation	73.2	66.0	84.6	70.1	59.9	48.5	54.9	34.5	60.7	98.8	75.9	78.2	805.4
		Rain and melt	16.5	16.8	128.8	183.9							75.9	21.8	801.0
		Surface runoff	24.9	27.1	66.6	97.6	31.6	19.8	23.7	20.5	20.6	23.7	24.8	23.4	404.3
		Ground water runoff	20.3	24.4	32.3	59.7	26.4	18.3	17.8	16.5	15.5	15.1	20.1	21.3	287.7
		Ground water recharge	11.9	14.4	94.5	111.5	0.0	0.0	0.0	0.0	0.0	0.0	30.0	19.7	282.0
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	55.6	64.5	54.7	62.5	47.0	13.5	0.0	402.7
		Change in ground water storage	-8.3	-10.3	+62.2	+51.8	-26.4	-18.3	-17.8	-16.5	-15.5	-15.1	+9.9	-1.6	-5.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-15.7	-8.6	-15.5	-24.2	-6.9	+43.2	+27.7	0.0	0.0
	1971	Precipitation	85.6	123.4	59.9	37.6	33.8	94.0	88.1	54.1	52.3	47.2	77.2	115.1	870.7
		Rain and melt	8.1	77.7	40.6	236.7							61.0	96.0	889.6
		Surface runoff	24.9	26.6	31.6	91.8	28.8	21.9	21.5	19.7	19.5	20.8	20.9	25.0	353.0
		Ground water runoff	20.1	22.1	27.2	46.5	23.6	17.8	16.8	16.0	15.0	14.5	13.0	21.1	253.7
		Ground water recharge	3.3	73.2	36.2	170.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.7	308.7
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	105.3	101.2	80.7	56.1	48.5	2.5	0.0	481.6
		Change in ground water storage	-16.8	+51.1	+9.0	+123.8	-23.6	-17.8	-16.8	-16.0	-15.0	-14.5	-13.0	+4.6	+55.0
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-37.7	-15.3	-17.8	-30.3	-8.3	-7.6	+50.6	+66.4	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-3	1972	Precipitation	54.6	99.8	101.9	71.9	51.9	89.1	90.2	113.2	77.1	86.6	74.6	134.0	1044.9
		Rain and melt	29.5	21.6	82.7	221.7							73.8	74.2	1011.6
		Surface runoff	29.6	25.7	45.5	128.8	37.8	26.6	25.1	26.4	24.1	31.5	32.5	41.2	474.8
		Ground water runoff	22.1	21.3	25.9	55.4	32.3	22.1	20.3	19.1	18.3	17.4	27.2	29.5	310.9
		Ground water recharge	22.0	17.2	63.1	132.6	0.0	0.0	0.0	0.0	0.0	0.0	41.7	62.5	339.1
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	95.5	102.3	107.7	78.2	27.4	2.3	0.0	508.6
		Change in ground water storage	-0.1	-4.1	+37.2	+77.2	-32.3	-22.1	-20.3	-19.1	-18.3	-17.4	+14.5	+33.0	+28.2
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-33.1	-10.9	-16.9	-1.8	-6.9	+45.1	+24.5	0.0	0.0
	1973	Precipitation	37.4	45.3	118.5	82.3	94.4	65.6	37.2	69.9	43.5	107.9	95.8	71.8	869.6
		Rain and melt	81.0	28.8	152.0								95.8	40.9	899.3
		Surface runoff	52.7	39.5	86.9	59.1	42.6	29.7	21.7	23.7	21.4	26.1	33.7	33.6	470.7
		Ground water runoff	30.7	24.6	36.9	34.2	35.1	24.3	19.4	18.7	17.9	16.7	24.8	26.1	309.4
		Ground water recharge	59.0	13.9	88.3	28.7	25.4	0.0	0.0	0.0	0.0	0.0	49.2	33.4	297.9
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	90.2	65.2	78.2	48.8	44.2	9.6	0.0	440.1
		Change in ground water storage	+28.3	-10.7	+51.4	-5.5	-9.7	-24.3	-19.4	-18.7	-17.9	-16.7	+24.4	+7.3	-11.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-30.0	-30.3	-13.3	-8.8	+54.3	+28.1	0.0	0.0
S-4	1968	Precipitation	72.1	41.7	55.4	25.7	97.5	59.9	11.4	71.6	64.3	55.4	114.6	84.1	753.6
		Rain and melt	25.7	63.9	86.6								113.7	49.1	724.8
		Surface runoff	9.1	43.9	91.4	24.4	18.3	8.1	3.3	3.6	4.1	6.3	17.2	15.0	244.7
		Ground water runoff	6.3	10.2	14.6	18.0	10.7	6.3	2.8	2.5	2.3	2.0	12.0	8.9	96.6
		Ground water recharge	22.9	30.2	9.6	0.0	5.1	0.0	0.0	0.0	0.0	0.0	25.8	43.0	136.6
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	33.5	78.0	67.8	45.0	7.6	0.0	440.1
		Change in ground water storage	+16.6	+20.0	-5.0	-18.0	+5.6	-6.3	-2.8	-2.5	-2.3	-2.0	+13.8	+34.1	+40.0
		Change in soil moisture storage	0.0	0.0	0.0	-19.8	+19.8	-45.8	-22.6	-7.5	-5.3	+6.1	+75.1	0.0	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-1	1972	Precipitation	62.2	109.7	87.9	69.3	55.1	97.0	83.6	115.8	77.0	89.2	70.6	148.8	1064.3
		Rain and melt	25.4	28.4	66.8	244.1							69.9	88.9	1041.2
		Surface runoff	24.8	24.0	33.1	125.2	37.1	24.9	24.1	24.1	22.0	27.3	29.1	37.1	432.8
		Ground water runoff	22.6	22.1	26.2	47.2	31.5	21.6	21.0	20.0	19.0	18.0	26.2	34.8	310.2
		Ground water recharge	23.2	26.5	59.9	150.4	0.0	0.0	0.0	0.0	0.0	11.6	64.7	86.6	422.9
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	97.0	88.6	107.7	77.5	27.4	2.3	0.0	496.3
		Change in ground water storage	-0.6	+4.4	+33.7	+103.2	-31.5	-21.6	-21.0	-20.0	-19.0	-6.4	+38.5	+51.8	+112.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-30.0	-3.3	-8.1	+4.0	-3.5	+40.9	0.0	0.0	0.0
	1973	Precipitation	30.7	45.5	117.1	91.7	94.2	68.8	40.1	71.6	42.2	112.3	101.6	94.7	910.6
		Rain and melt	68.1	35.0	149.1								101.6	46.5	921.2
		Surface runoff	50.5	30.7	103.1	56.6	38.3	25.6	21.6	22.1	20.6	23.1	26.9	27.2	446.3
		Ground water runoff	32.5	20.1	43.4	37.1	30.7	21.6	20.3	19.3	18.6	17.6	22.2	23.1	306.5
		Ground water recharge	50.1	24.4	75.7	43.5	25.1	0.0	0.0	0.0	0.0	0.0	39.0	42.4	300.2
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	80.3	77.5	55.5	44.2	9.6	0.0	481.2
		Change in ground water storage	+17.6	+4.3	+32.3	+6.4	-5.6	-21.6	-20.3	-19.3	-18.6	-17.6	+16.8	+19.3	-6.3
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-45.4	-41.5	-8.7	-15.3	+62.6	+48.2	0.0	0.0
S-2	1968	Precipitation	64.8	48.3	59.9	26.7	107.4	61.2	22.4	85.9	84.8	57.4	113.5	80.8	813.1
		Rain and melt	-	-	-	-							-	-	-
		Surface runoff	27.7	44.4	86.0	36.8	36.6	24.1	16.3	19.8	22.9	23.6	33.8	29.0	401.0
		Ground water runoff	23.4	25.4	39.4	30.5	26.9	20.6	15.2	14.0	12.3	11.1	13.9	24.8	257.5
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	85.1	89.9	85.1	45.0	7.6	0.0	520.9
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-2	1969	Precipitation	66.0	18.5	38.9	91.4	87.9	67.3	106.7	96.5	10.2	66.0	100.6	61.7	811.8
		Rain and melt	-	-	-	-							88.8	24.9	-
		Surface runoff	50.0	26.2	69.3	54.1	39.9	27.4	24.6	31.7	15.7	21.6	31.2	24.9	416.6
		Ground water runoff	23.6	21.3	25.5	38.1	30.5	23.1	18.5	16.6	15.5	14.0	24.1	21.1	271.9
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	122.9	109.5	28.4	37.6	12.9	0.0	513.7
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-
	1970	Precipitation	53.3	35.6	72.9	75.9	62.7	43.2	91.7	33.0	65.8	105.9	68.8	76.2	785.1
		Rain and melt	18.8	23.5	132.0	112.0							68.7	36.9	794.2
		Surface runoff	17.5	24.4	57.9	61.2	30.0	17.5	20.1	16.3	19.3	24.4	28.4	26.2	343.1
		Ground water runoff	15.7	20.3	31.5	42.7	24.6	16.3	16.0	15.2	14.0	13.3	24.4	22.9	256.9
		Ground water recharge	17.0	19.4	105.6	59.0	0.0	0.0	0.0	0.0	0.0	0.0	16.8	33.6	251.4
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	100.8	95.5	37.2	57.6	47.0	13.5	0.0	456.6
		Change in ground water storage	+1.3	-0.9	+74.1	+16.3	-24.6	-16.3	-16.0	-15.2	-14.0	-13.3	-7.6	+10.7	-5.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-13.1	-58.8	-7.9	-5.3	+2.9	+47.8	+34.4	0.0	0.0
	1971	Precipitation	66.8	107.7	69.3	33.5	30.2	144.8	85.1	61.2	63.5	50.3	62.0	102.1	876.6
		Rain and melt	12.1	61.1	65.9	186.3							49.1	88.6	898.2
		Surface runoff	22.1	25.9	38.5	95.0	25.9	24.1	20.6	16.0	18.3	19.6	22.1	30.7	358.6
		Ground water runoff	19.8	21.1	30.7	46.5	24.9	18.5	16.3	13.7	12.0	11.3	10.6	22.3	247.7
		Ground water recharge	9.8	56.3	58.1	116.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6	258.5
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	103.6	112.8	103.6	67.1	51.6	2.5	0.0	528.8
		Change in ground water storage	-10.0	+35.2	+27.4	+70.2	-24.9	-18.5	-16.3	-13.7	-12.0	-11.3	-10.6	-4.7	+10.8
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-37.1	+35.6	-32.0	-44.7	-9.9	-9.6	+35.1	+62.6	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-2	1972	Precipitation	55.1	94.0	115.3	73.4	50.8	84.6	93.7	118.1	84.1	93.7	73.7	122.4	1058.9
		Rain and melt	22.3	22.1	89.5	230.3							72.8	81.8	1043.8
		Surface runoff	24.1	22.6	40.6	148.8	34.8	23.6	21.8	23.4	19.3	28.7	32.0	38.3	458.2
		Ground water runoff	18.8	18.5	26.9	44.4	29.7	19.0	18.0	17.8	15.7	14.6	25.9	26.7	276.0
		Ground water recharge	17.0	18.0	75.8	110.2	0.0	0.0	0.0	0.0	0.0	0.0	47.2	70.2	338.4
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	96.0	114.0	107.7	80.8	27.4	2.3	0.0	523.7
		Change in ground water storage	-1.8	-0.5	+48.9	+65.8	-29.7	-19.0	-18.0	-17.8	-15.7	-14.6	+21.3	+43.5	+62.4
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-33.8	-16.0	-24.1	+4.8	-0.3	+52.2	+17.2	0.0	0.0
	1973	Precipitation	42.2	42.9	118.4	90.2	112.5	66.8	38.4	78.0	67.1	111.8	103.4	73.2	944.6
		Rain and melt	77.4	27.4	140.2	90.2							103.4	48.2	961.4
		Surface runoff	46.0	36.1	109.2	61.2	38.6	23.9	15.5	17.5	14.2	19.8	27.7	25.4	435.1
		Ground water runoff	27.4	20.3	39.1	38.1	29.7	20.1	14.7	14.0	13.0	12.6	24.1	21.2	274.3
		Ground water recharge	58.8	11.6	56.4	38.4	42.1	0.0	0.0	0.0	0.0	0.0	45.8	44.0	297.1
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	81.7	85.6	68.3	44.2	9.6	0.0	503.6
		Change in ground water storage	+31.4	-8.7	+17.3	+0.3	+12.4	-20.1	-14.7	-14.0	-13.0	-12.6	+21.7	+22.8	+22.8
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-47.2	-44.1	-11.1	-2.4	+60.4	+44.4	0.0	0.0
S-3	1968	Precipitation	71.7	58.5	61.3	28.0	105.3	59.5	14.8	83.9	81.1	59.1	117.4	90.8	831.4
		Rain and melt	31.9	58.1	152.1								96.6	35.1	805.5
		Surface runoff	30.5	46.7	93.7	38.6	36.1	27.4	21.9	23.9	24.5	24.8	32.3	33.0	433.4
		Ground water runoff	27.7	27.9	38.9	34.5	28.7	24.4	20.6	19.3	18.8	17.3	24.1	29.2	311.4
		Ground water recharge	29.1	39.3	97.3	0.0	17.7	0.0	0.0	0.0	0.0	0.0	44.3	31.3	259.0
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	80.9	17.0	87.9	82.0	45.0	7.6	0.0	424.5
		Change in ground water storage	+1.4	+11.4	+58.4	-34.5	-11.0	-24.4	-20.6	-19.3	-18.8	-17.3	+20.2	+2.1	-52.4
		Change in soil moisture storage	0.0	0.0	0.0	-15.2	+15.2	-24.4	-3.5	-8.6	-6.6	+6.6	+36.5	0.0	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-3	1969	Precipitation	60.8	24.2	38.8	93.1	87.4	73.8	105.9	113.2	8.2	62.1	109.1	68.3	844.9
		Rain and melt	97.7	10.8	56.1	128.6							93.8	29.4	867.0
		Surface runoff	65.2	27.3	54.3	51.0	36.8	27.8	25.3	29.7	19.7	24.5	30.3	29.8	421.7
		Ground water runoff	28.4	24.9	30.7	35.0	27.9	23.9	21.6	18.8	17.5	16.5	24.1	25.1	294.4
		Ground water recharge	60.9	8.4	32.5	77.0	11.2	0.0	0.0	0.0	0.0	8.2	74.7	24.7	297.5
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	75.5	102.6	96.4	14.3	37.6	12.9	0.0	442.2
		Change in ground water storage	+32.5	-16.5	+1.8	+42.0	-16.7	-23.9	-21.6	-18.8	-17.5	-16.5	+50.6	-0.4	+3.1
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-5.5	-0.4	+5.9	-8.3	+8.3	0.0	0.0	0.0
	1970	Precipitation	61.9	50.3	76.3	72.9	60.7	48.7	71.9	33.6	54.0	107.3	71.4	76.6	785.6
		Rain and melt	17.6	20.5	130.7	146.3							71.4	32.3	795.0
		Surface runoff	28.0	25.6	61.1	62.1	35.6	23.6	25.8	20.7	23.1	27.6	31.4	32.1	396.7
		Ground water runoff	25.1	23.1	29.7	43.2	30.5	22.6	21.3	19.8	17.8	15.9	25.6	22.9	297.5
		Ground water recharge	14.7	18.2	99.3	92.9	0.0	0.0	0.0	0.0	0.0	0.0	28.6	23.1	276.8
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	78.2	70.8	46.7	57.5	47.0	13.5	0.0	418.6
		Change in ground water storage	-10.4	-4.9	+69.6	+49.7	-30.5	-22.6	-21.3	-19.8	-17.8	-15.9	+3.0	+0.2	-20.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-14.8	-31.1	-3.4	-14.0	-8.8	+48.6	+23.5	0.0	0.0
	1971	Precipitation	67.9	113.8	54.7	36.4	31.8	109.5	83.6	59.8	54.8	52.1	68.2	96.6	829.2
		Rain and melt	7.2	50.1	51.9	208.0							51.2	86.3	846.3
		Surface runoff	31.3	39.4	45.5	97.0	29.4	25.3	23.6	18.5	20.6	22.4	24.5	32.4	409.9
		Ground water runoff	25.9	24.1	34.8	50.2	24.3	19.6	19.0	17.8	16.8	15.3	14.3	24.9	287.0
		Ground water recharge	1.8	34.8	41.2	140.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	78.1	296.0
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	87.3	85.0	63.2	54.1	47.9	2.5	0.0	427.4
		Change in ground water storage	-24.1	+10.7	+6.4	+89.9	-24.3	-19.6	-19.0	-17.8	-16.8	-15.3	-14.3	+53.2	+9.0
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-39.6	+16.5	-6.0	-4.1	-3.1	-2.9	+38.5	+0.7	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
02HD007															
	1969	Precipitation	60.7	17.3	37.1	90.4	86.4	69.6	102.9	102.1	12.2	64.8	103.1	61.0	807.5
		Rain and melt	-	-	-	-							90.3	32.6	-
		Surface runoff	101.3	30.7	52.1	57.4	35.6	23.4	17.3	21.6	12.2	15.0	25.4	27.4	419.4
		Ground water runoff	53.2	24.6	33.6	35.5	23.3	18.3	14.6	13.3	12.0	11.5	18.9	21.8	280.7
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	119.6	108.2	23.4	37.6	13.0	0.0	503.4
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-
	1970	Precipitation	53.6	39.4	68.3	71.4	67.6	55.4	78.2	37.1	53.6	115.1	70.1	77.7	787.5
		Rain and melt	18.7	32.9	114.2	108.1							63.9	48.3	793.1
		Surface runoff	16.8	35.3	80.5	55.6	26.7	14.0	13.5	11.2	12.7	15.5	23.4	27.4	332.6
		Ground water runoff	15.8	19.7	40.7	34.9	19.7	11.3	11.1	10.3	9.9	9.5	17.0	21.9	221.8
		Ground water recharge	17.7	17.3	74.4	52.9	0.0	0.0	0.0	0.0	0.0	0.0	12.6	42.8	217.7
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	103.6	90.2	50.3	55.1	47.0	13.5	0.0	464.6
		Change in ground water storage	+1.9	-2.4	+33.7	+18.0	-19.7	-11.3	-11.1	-10.3	-9.9	-9.5	-7.9	+8.9	-4.1
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-9.8	-50.9	-14.4	-14.1	-4.3	+62.1	+31.4	0.0	0.0
	1971	Precipitation	52.3	99.6	47.8	46.7	31.0	117.3	75.4	74.9	54.1	56.6	61.0	94.0	810.8
		Rain and melt	11.0	53.7	70.1	147.2							47.7	86.1	825.1
		Surface runoff	17.0	51.8	61.0	87.4	16.8	14.7	11.2	9.4	11.2	12.7	16.3	30.7	340.2
		Ground water runoff	11.7	19.3	40.4	40.9	15.5	9.7	9.0	8.0	7.1	5.9	5.0	21.3	193.8
		Ground water recharge	5.7	21.2	49.5	79.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.1	180.0
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	103.6	108.2	80.8	59.2	56.9	2.5	0.0	498.7
		Change in ground water storage	-6.0	+1.9	+9.1	+38.7	-15.5	-9.7	-9.0	-8.0	-7.1	-5.9	-5.0	+2.8	-13.8
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-36.6	+8.7	-35.0	-7.3	-9.2	-7.1	+33.9	+52.6	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-4	1969	Precipitation	61.5	15.0	33.3	89.4	84.6	66.8	104.1	92.7	14.5	65.0	98.6	58.9	784.4
		Rain and melt	95.5	13.9	32.7	93.0							86.7	43.0	792.5
		Surface runoff	96.8	21.1	24.9	50.8	25.6	10.2	7.4	16.5	4.1	7.6	16.3	22.1	303.4
		Ground water runoff	17.1	16.0	11.2	22.1	15.0	7.4	6.3	5.3	3.5	3.0	11.1	13.1	131.1
		Ground water recharge	15.8	8.8	19.0	28.7	6.7	0.0	0.0	0.0	0.0	0.0	16.1	34.0	129.1
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	115.8	98.5	24.9	37.6	12.9	0.0	491.1
		Change in ground water storage	-1.3	-7.2	+7.8	+6.6	-8.3	-7.4	-6.3	-5.3	-3.5	-3.0	+5.0	+20.9	-2.0
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-34.5	-12.8	-17.0	-11.0	+22.8	+52.5	0.0	0.0
	1970	Precipitation	46.7	39.1	58.7	67.3	70.1	64.8	88.9	32.5	41.4	125.0	58.4	71.1	764.0
		Rain and melt	20.2	35.4	100.5	83.5							58.4	37.5	758.2
		Surface runoff	11.9	31.0	57.7	46.0	16.5	15.7	6.1	2.5	3.6	8.9	15.2	18.0	233.2
		Ground water runoff	5.4	8.6	12.8	21.8	9.1	8.3	4.2	2.1	2.0	1.8	9.4	12.8	98.3
		Ground water recharge	13.7	13.0	55.6	24.8	0.0	0.0	0.0	0.0	0.0	0.0	19.9	32.3	159.3
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	101.8	103.4	46.5	47.0	47.0	13.5	0.0	464.1
		Change in ground water storage	+8.3	+4.4	+42.8	+3.0	-9.1	-8.3	-4.2	-2.1	-2.0	-1.8	+10.5	+19.5	+61.0
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-7.7	-44.4	-16.4	-14.4	-7.2	+70.9	+19.2	0.0	0.0
	1971	Precipitation	41.1	94.0	31.7	26.2	30.5	114.6	66.0	87.1	47.0	61.5	58.4	91.9	750.1
		Rain and melt	6.5	83.0	60.9	76.2							46.5	87.4	767.2
		Surface runoff	8.4	103.9	95.0	53.8	8.1	6.1	4.6	3.5	4.3	5.6	6.3	16.0	315.7
		Ground water runoff	6.9	21.6	35.4	16.2	7.6	4.1	3.0	2.3	2.0	1.8	1.8	9.1	111.8
		Ground water recharge	5.0	0.7	1.3	17.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.4	68.9
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	103.6	99.3	90.7	53.1	57.9	2.5	0.0	494.4
		Change in ground water storage	-1.9	-20.9	-34.1	+1.3	-7.6	-4.1	-3.0	-2.3	-2.0	-1.8	-1.8	+35.3	-42.9
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-36.3	+9.0	-34.9	-4.8	-8.4	-0.2	+39.5	+36.1	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
S-4	1972	Precipitation	32.5	69.3	91.4	71.6	52.8	80.5	90.4	111.3	69.6	77.7	74.7	120.1	942.1
		Rain and melt	17.4	14.2	111.1	138.5							73.9	101.5	938.9
		Surface runoff	9.4	9.6	106.4	108.2	15.0	6.9	6.3	8.6	5.1	10.0	20.0	55.5	361.0
		Ground water runoff	6.6	7.8	22.7	25.4	10.9	6.1	5.1	4.6	3.3	3.1	13.4	20.3	129.3
		Ground water recharge	14.6	12.4	27.4	40.0	0.0	0.0	0.0	0.0	0.0	0.0	38.2	66.3	198.9
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	91.9	112.4	107.7	71.4	27.4	2.3	0.0	508.3
		Change in ground water storage	+8.0	+4.6	+4.7	+14.6	-10.9	-6.1	-5.1	-4.6	-3.3	-3.1	+24.8	+46.0	+69.6
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-30.8	-12.2	-23.2	-0.4	-3.6	+43.4	+26.8	0.0	0.0
	1973	Precipitation	39.1	36.1	104.4	74.4	95.2	62.2	33.8	52.6	44.2	102.1	81.0	56.6	781.8
		Rain and melt	53.4	25.4	120.2									46.1	795.9
		Surface runoff	48.5	43.0	112.5	58.6	21.0	9.0	4.0	3.6	2.9	5.6	10.9	14.4	334.0
		Ground water runoff	17.4	20.5	27.5	13.7	12.8	7.3	3.1	2.2	2.0	1.9	8.5	9.0	125.9
		Ground water recharge	22.3	2.9	21.5	0.8	25.5	0.0	0.0	0.0	0.0	0.0	43.3	40.7	157.0
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	49.8	64.3	48.8	44.2	9.6	0.0	430.8
		Change in ground water storage	+4.9	-17.6	-6.0	-12.9	+12.7	-7.3	-3.1	-2.2	-2.0	-1.9	+34.8	+31.7	+31.1
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-49.7	-16.9	-13.1	-5.5	+54.2	+31.0	0.0	0.0
02HD007	1968	Precipitation	70.4	45.7	57.4	26.4	102.4	61.2	15.7	78.0	74.9	56.9	113.0	81.0	808.5
		Rain and melt	-	-	-	-	-						-	-	-
		Surface runoff	-	-	-	-	-	-	8.4	11.9	12.2	12.9	22.6	23.4	-
		Ground water runoff	-	-	-	-	-	-	8.0	7.5	7.0	6.8	15.2	18.3	-
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	58.7	83.1	76.7	45.0	7.6	0.0	479.3
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
02HD007															
	1972	Precipitation	43.7	81.5	100.3	74.4	51.8	82.3	115.1	113.0	74.4	83.8	74.7	122.7	1017.8
		Rain and melt	26.7	25.1	94.3	175.0							73.4	85.0	999.9
		Surface runoff	29.7	16.3	44.7	145.3	24.9	16.8	15.0	14.2	12.9	23.1	31.2	48.0	422.1
		Ground water runoff	22.1	13.5	16.5	50.3	18.8	12.7	11.2	9.9	9.4	8.3	23.6	26.0	222.3
		Ground water recharge	19.1	22.3	66.1	64.3	0.0	0.0	0.0	0.0	0.0	0.0	42.0	63.0	276.8
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	93.7	119.6	107.7	77.4	27.4	2.3	0.0	523.3
		Change in ground water storage	-3.0	+8.8	+49.6	+14.0	-18.8	-12.7	-11.2	-9.9	-9.4	-8.3	+18.4	+37.0	+54.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-33.8	-15.5	-8.3	+1.0	-6.5	+41.6	+21.5	0.0	0.0
	1973	Precipitation	41.4	41.4	114.0	78.0	98.6	62.5	35.6	63.0	45.0	105.4	89.4	63.0	837.2
		Rain and melt	70.3	25.6	139.6	78.0							89.4	44.3	856.6
		Surface runoff	48.5	40.1	110.0	64.8	39.9	-	-	-	-	-	-	-	-
		Ground water runoff	-	-	-	-	-	-	-	-	-	-	-	-	-
		Ground water recharge	-	-	-	-	-	-	-	-	-	-	-	-	-
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	60.7	73.1	49.5	44.2	9.6	0.0	451.1
		Change in ground water storage	-	-	-	-	-	-	-	-	-	-	-	-	-
		Change in soil moisture storage	-	-	-	-	-	-	-	-	-	-	-	-	-
W-1	1968	Precipitation	70.1	70.9	66.5	29.2	106.9	56.9	12.2	94.2	82.6	60.4	126.5	111.0	887.5
		Rain and melt	24.4	52.1	148.3								126.0	49.8	843.0
		Surface runoff	26.7	26.7	38.6	27.9	27.7	26.4	25.6	26.2	26.7	29.7	31.2	30.2	343.7
		Ground water runoff	26.1	24.7	28.9	26.9	26.2	25.7	25.4	25.2	24.8	24.2	28.7	29.5	316.3
		Ground water recharge	23.8	50.1	138.4	0.0	29.5	0.0	0.0	0.0	0.0	0.0	4.6	49.1	295.5
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	82.3	97.0	80.1	45.0	7.6	0.0	520.1
		Change in ground water storage	-2.3	+25.4	+109.5	-26.9	+3.3	-25.7	-25.4	-24.4	-24.8	-24.2	-24.1	+19.6	-20.8
		Change in soil moisture storage	0.0	0.0	0.0	-10.9	+10.9	-47.7	-70.3	-3.8	+0.6	+9.9	+111.3	0.0	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-1	1969	Precipitation	65.0	32.0	38.1	97.0	87.9	74.2	119.4	117.6	8.6	59.2	109.0	78.7	886.7
		Rain and melt	108.5	11.2	73.2	100.6							90.6	44.5	895.6
		Surface runoff	30.7	27.7	38.6	34.0	28.2	28.2	30.7	28.7	24.1	30.0	30.7	28.2	359.9
		Ground water runoff	29.5	27.2	31.5	30.0	27.4	26.9	26.4	26.2	23.1	22.1	28.7	27.4	326.4
		Ground water recharge	107.3	10.7	66.1	61.0	19.8	0.0	0.0	0.0	0.0	0.0	42.3	43.7	350.9
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	104.7	110.1	44.4	37.6	12.9	0.0	511.2
		Change in ground water storage	+77.8	-16.5	+34.5	+31.0	-7.6	-26.9	-26.4	-26.2	-23.1	-22.1	+13.6	+16.3	+24.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-25.6	+10.4	+5.0	-36.8	+13.6	+33.4	0.0	0.0
	1970	Precipitation	73.2	66.0	84.6	70.1	59.9	48.5	54.9	34.5	60.7	98.8	75.9	78.2	805.4
		Rain and melt	16.5	16.8	128.8	183.9							75.9	21.8	801.0
		Surface runoff	27.4	24.6	28.2	36.3	29.5	26.7	28.7	26.2	26.4	31.2	30.5	29.2	344.7
		Ground water runoff	26.4	24.2	26.5	31.8	28.6	25.8	25.7	25.2	25.0	24.2	23.0	26.2	312.6
		Ground water recharge	15.5	16.4	127.1	144.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	306.5
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	99.8	86.8	47.2	63.0	47.0	13.5	0.0	462.4
		Change in ground water storage	-10.9	-7.8	+100.6	+113.1	-28.6	-25.8	-25.7	-25.2	-25.0	-24.2	-23.2	-23.6	-6.1
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-11.4	-52.2	-34.9	-13.7	-3.7	+44.8	+54.9	+16.2	0.0
	1971	Precipitation	85.6	123.4	59.9	37.6	33.8	94.0	88.1	54.1	52.3	47.2	77.2	115.1	870.7
		Rain and melt	8.1	77.7	40.6	236.7							61.0	96.0	889.6
		Surface runoff	27.7	26.7	30.5	36.6	24.1	22.6	24.6	23.6	24.6	27.7	26.9	29.5	325.1
		Ground water runoff	26.9	25.6	29.7	31.5	23.6	22.5	22.1	22.0	21.6	21.0	20.0	26.9	293.4
		Ground water recharge	7.3	76.6	39.8	210.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	350.4
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	111.8	110.2	88.9	57.7	49.0	2.5	0.0	507.5
		Change in ground water storage	-19.6	+51.0	+10.1	+179.0	-23.6	-22.5	-22.1	-22.0	-21.6	-21.0	-20.0	-10.7	+57.0
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-33.0	-17.9	-24.6	-36.4	-8.4	-8.5	+51.6	+77.2	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-1	1972	Precipitation	62.2	109.7	87.9	69.3	55.1	97.0	83.6	115.8	77.0	89.2	70.6	148.8	1064.3
		Rain and melt	25.4	28.4	66.8	244.1							69.9	88.9	1041.2
		Surface runoff	25.1	23.1	26.1	40.4	28.4	26.4	24.9	25.1	24.6	28.2	27.4	26.9	326.9
		Ground water runoff	24.0	22.4	24.9	29.4	26.8	24.1	23.7	23.6	23.3	26.7	26.4	25.2	300.5
		Ground water recharge	24.3	27.7	65.6	217.4	0.0	0.0	0.0	0.0	0.0	32.9	66.6	87.2	521.7
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	97.5	113.0	107.7	77.7	27.4	2.3	0.0	521.5
		Change in ground water storage	+0.3	+5.3	+40.7	+188.0	-26.8	-24.1	-23.7	-23.6	-23.3	+6.2	+40.2	+62.0	+221.2
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-26.0	-2.8	-30.6	+6.6	-2.0	+54.8	0.0	0.0	0.0
	1973	Precipitation	30.7	45.5	117.1	91.7	94.2	68.8	40.1	71.6	42.2	112.3	101.6	94.7	910.6
		Rain and melt	68.1	35.0	149.1								101.6	46.5	921.2
		Surface runoff	27.4	24.4	48.8	31.5	30.2	26.4	24.9	27.7	25.9	32.8	35.6	30.7	366.3
		Ground water runoff	25.6	22.6	33.1	28.7	28.2	26.1	24.7	24.1	24.1	23.9	33.1	27.1	321.3
		Ground water recharge	66.3	33.2	119.7	60.2	30.7	0.0	0.0	0.0	0.0	0.0	12.2	42.9	365.2
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	90.2	80.3	72.6	44.2	9.6	0.0	511.0
		Change in ground water storage	+40.7	+10.6	+86.6	+31.5	+2.5	-26.1	-24.7	-24.1	-24.1	-23.9	-20.9	+15.8	+43.9
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-41.7	-50.3	-12.3	-32.2	+59.2	+77.3	0.0	0.0
W-2	1968	Precipitation	70.1	70.9	66.5	29.2	106.9	56.9	12.2	94.2	82.6	60.4	126.5	111.0	887.5
		Rain and melt	34.4	52.1	148.3	29.2							126.0	49.8	853.0
		Surface runoff	29.6	35.6	63.8	36.8	35.2	28.7	21.9	25.5	25.6	28.7	34.7	33.5	399.6
		Ground water runoff	26.2	25.9	32.9	35.0	29.6	26.6	21.3	20.7	20.0	19.4	28.7	31.2	317.5
		Ground water recharge	31.0	42.4	117.2	0.0	24.6	0.0	0.0	0.0	0.0	0.0	18.0	47.5	280.7
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	103.9	50.3	96.0	83.1	45.0	7.6	0.0	490.2
		Change in ground water storage	+4.8	+16.5	+84.3	-35.0	-5.0	-26.6	-21.3	-20.7	-20.0	-19.4	-10.7	+16.3	-36.8
		Change in soil moisture storage	0.0	0.0	0.0	-11.7	+11.7	-49.1	-38.7	-6.6	-6.1	+6.1	+94.4	0.0	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-2	1969	Precipitation	65.0	32.0	38.1	97.0	87.9	74.2	119.4	117.6	8.6	59.2	109.0	78.7	886.7
		Rain and melt	108.5	11.2	73.2	100.6							90.6	44.5	895.5
		Surface runoff	40.5	25.7	50.0	48.2	33.8	27.7	29.3	33.3	25.1	30.1	35.9	35.7	415.3
		Ground water runoff	29.9	24.7	28.6	38.0	31.0	25.5	23.5	22.3	20.9	20.5	32.0	33.6	330.5
		Ground water recharge	97.9	10.2	51.8	54.8	17.8	0.0	0.0	0.0	0.0	0.0	58.1	42.4	333.0
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	100.4	108.1	17.3	37.6	12.9	0.0	477.7
		Change in ground water storage	+68.0	-14.5	+23.2	+16.8	-13.2	-25.5	-23.5	-22.3	-20.9	-20.5	+26.1	+8.8	+2.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-26.5	+13.2	-1.5	-12.9	+12.0	+15.7	0.0	0.0
	1970	Precipitation	73.2	66.0	84.6	70.1	59.9	48.5	54.9	34.5	60.7	98.8	75.9	78.2	805.4
		Rain and melt	16.5	16.8	128.8	183.9								21.8	801.0
		Surface runoff	27.3	22.6	33.5	50.2	33.5	25.0	28.6	24.5	25.9	33.5	38.6	34.9	378.1
		Ground water runoff	25.5	20.9	26.2	34.5	31.1	23.4	23.0	22.2	20.9	19.4	19.0	31.8	297.9
		Ground water recharge	14.7	15.1	121.5	133.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	297.3
		Actual evapotranspiration	0.0	0.0	0.0	34.9	70.4	85.6	64.5	44.7	62.5	47.0	13.5	0.0	423.5
		Change in ground water storage	-10.8	-5.8	+95.3	+98.8	-31.1	-23.4	-23.0	-22.2	-20.9	-19.4	-19.0	-19.1	-0.6
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-12.9	-39.1	-15.2	-12.5	-6.8	+37.7	+42.8	+6.0	0.0
	1971	Precipitation	85.6	123.4	59.9	37.6	33.8	94.0	88.1	54.1	52.3	47.2	77.2	115.1	870.7
		Rain and melt	8.1	77.7	40.6	236.7							61.0	96.0	889.6
		Surface runoff	29.0	30.3	35.2	56.8	34.9	29.9	27.3	23.3	25.6	29.2	29.8	36.0	387.3
		Ground water runoff	27.1	26.6	33.6	41.7	33.2	27.6	24.3	21.6	20.8	20.6	19.6	31.1	328.8
		Ground water recharge	6.2	74.0	39.0	200.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.8	343.5
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	110.2	106.2	75.7	56.1	48.5	2.5	0.0	487.6
		Change in ground water storage	-20.9	+47.4	+5.4	+158.8	-33.2	-27.6	-24.3	-21.6	-20.8	-20.6	-19.6	-7.3	+14.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-34.2	-18.5	-21.1	-23.3	-8.6	-9.9	+48.3	+67.3	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-2	1972	Precipitation	62.2	109.7	87.9	69.3	55.1	97.0	83.6	115.8	77.0	89.2	70.6	146.8	1064.3
		Rain and melt	25.4	28.4	66.8	244.1							69.9	88.9	1041.2
		Surface runoff	31.7	27.0	32.9	69.9	38.8	31.5	30.0	32.8	28.3	34.3	36.6	39.8	433.6
		Ground water runoff	30.8	26.5	30.2	42.7	35.4	26.2	25.5	23.9	21.3	20.8	31.3	35.9	350.5
		Ground water recharge	24.5	27.9	64.1	201.2	0.0	0.0	0.0	0.0	0.0	0.0	39.6	85.0	442.3
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	97.0	108.7	107.7	77.5	27.4	2.3	0.0	515.8
		Change in ground water storage	-6.3	+1.4	+33.9	+158.5	-35.4	-26.2	-25.5	-23.9	-21.3	-20.8	+8.3	+49.1	+91.8
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-27.8	-5.3	-29.6	-0.8	-7.5	+48.3	+22.7	0.0	0.0
	1973	Precipitation	30.7	45.5	117.1	91.7	94.2	68.8	40.1	71.6	42.2	112.3	101.6	94.7	910.6
		Rain and melt	68.1	35.0	149.1									46.5	921.2
		Surface runoff	40.3	36.4	67.9	43.6	38.8	29.8	25.0	27.7	25.2	31.3	37.3	34.8	437.9
		Ground water runoff	33.7	31.3	39.6	37.2	34.8	27.1	23.6	22.9	21.7	20.6	34.5	31.7	358.7
		Ground water recharge	61.5	29.9	107.1	56.6	28.7	0.0	0.0	0.0	0.0	0.0	22.8	43.4	350.0
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	75.7	77.5	70.9	44.2	9.6	0.0	492.0
		Change in ground water storage	+27.8	-1.4	+67.5	+19.4	-6.1	-27.1	-23.6	-22.9	-21.7	-20.6	-11.7	+11.7	-8.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-44.1	-37.0	-10.7	-32.2	+57.6	+66.4	0.0	0.0
W-3	1968	Precipitation	54.9	38.1	43.7	26.2	81.0	55.1	12.2	65.3	54.3	53.3	94.5	68.1	646.7
		Rain and melt	29.7	49.2	73.5									44.1	638.4
		Surface runoff	10.9	41.1	82.8	24.6	21.1	7.1	2.3	2.0	2.5	3.6	14.2	13.7	226.1
		Ground water runoff	8.2	9.4	10.4	13.3	6.5	3.4	1.9	1.3	1.1	1.0	1.0	4.2	61.7
		Ground water recharge	27.0	17.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	53.4
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	73.9	63.4	72.4	54.2	45.0	7.6	0.0	420.6
		Change in ground water storage	+18.8	+8.1	-9.5	-13.3	-6.5	-3.4	-1.9	-1.3	-1.1	-1.0	-1.0	+3.8	-8.3
		Change in soil moisture storage	0.0	0.0	0.0	-24.2	+1.4	-55.5	-51.6	-7.8	-1.3	+5.7	+73.7	+26.6	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-3	1969	Precipitation	52.3	10.9	33.8	94.0	87.1	65.5	130.0	91.2	10.4	82.5	97.5	62.2	817.6
		Rain and melt	66.3	15.3	37.0	96.4							87.5	44.2	813.4
		Surface runoff	59.2	18.5	47.0	50.3	26.7	13.7	13.0	11.7	2.3	5.3	18.0	18.3	284.0
		Ground water runoff	3.6	6.9	10.5	17.4	12.7	6.1	1.9	1.5	1.2	1.1	3.8	9.4	77.1
		Ground water recharge	10.7	3.7	0.5	27.9	5.8	0.0	0.0	0.0	0.0	0.0	4.8	35.3	88.7
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	119.7	107.9	37.3	37.6	12.9	0.0	517.8
		Change in ground water storage	+7.1	-3.2	-10.0	+10.5	-6.9	-6.1	-1.9	-1.5	-1.2	-1.1	+1.0	+25.9	+11.6
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-40.6	-0.8	-26.9	-28.0	+40.7	+55.6	0.0	0.0
	1970	Precipitation	57.4	43.7	67.1	75.7	75.9	70.9	88.6	33.5	43.4	116.6	58.7	68.6	800.1
		Rain and melt	18.3	30.6	132.3	90.6								39.9	799.3
		Surface runoff	8.1	11.7	59.9	59.9	24.5	8.9	7.9	2.5	2.5	8.6	16.8	16.0	228.3
		Ground water runoff	7.4	8.2	9.2	14.1	12.2	4.4	3.7	1.8	1.5	1.4	1.3	10.7	75.9
		Ground water recharge	17.6	27.1	81.6	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.7	154.3
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	102.1	121.0	55.4	48.8	47.0	13.5	0.0	492.6
		Change in ground water storage	+10.2	+18.9	+72.4	-3.8	-12.2	-4.4	-3.7	-1.8	-1.5	-1.4	-1.3	+10.0	+78.4
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-6.8	-35.7	-37.5	-22.6	-6.4	+62.4	+29.7	+16.9	0.0
	1971	Precipitation	56.1	73.9	54.6	26.9	32.0	106.7	74.2	62.2	47.5	58.9	61.0	88.6	742.7
		Rain and melt	9.5	25.8	54.6	127.6							51.0	88.6	738.5
		Surface runoff	9.1	15.7	48.5	104.1	13.7	9.6	4.8	2.0	2.8	5.1	6.9	18.8	241.3
		Ground water runoff	8.6	8.1	15.8	24.6	11.1	3.8	2.3	1.3	1.0	0.9	0.6	7.0	86.0
		Ground water recharge	9.0	18.2	21.9	27.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.2	95.3
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	103.6	106.7	75.4	53.8	57.9	2.5	0.0	487.2
		Change in ground water storage	+0.4	+10.1	+6.1	+2.4	-11.1	-3.8	-2.3	-1.3	-1.0	-0.9	-0.6	+12.2	+9.3
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-36.9	-2.7	-35.0	-13.9	-8.1	-3.2	+42.2	+57.6	0.0

Table 31(cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
W-3	1972	Precipitation	59.2	80.0	66.3	54.6	45.0	81.5	100.1	120.1	76.7	76.2	59.4	112.3	931.4
		Rain and melt	40.9	13.9	71.3	144.9								110.4	940.4
		Surface runoff	14.7	14.5	40.1	136.9	23.1	9.9	10.9	18.3	7.6	17.3	29.5	39.1	361.9
		Ground water runoff	7.8	7.7	8.1	26.8	12.9	4.6	4.0	3.7	3.7	3.3	2.7	20.8	106.1
		Ground water recharge	34.0	7.1	39.3	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.3	164.8
		Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	94.2	114.0	107.7	79.0	27.4	2.3	0.0	520.2
		Change in ground water storage	+26.2	-0.6	+31.2	-7.7	-12.9	-4.6	-4.0	-3.7	-3.7	-3.3	-2.7	+44.5	+58.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-44.7	-18.0	-20.8	-2.2	-6.2	+34.8	+30.3	+26.8	0.0
	1973	Precipitation	36.3	43.2	93.7	76.2	96.5	80.5	29.7	38.4	46.0	95.8	81.0	64.5	781.8
		Rain and melt	43.1	24.2	107.8									44.1	763.3
		Surface runoff	50.3	23.6	81.8	59.7	38.6	15.5	3.9	3.1	2.8	6.2	15.8	14.5	315.8
		Ground water runoff	13.2	7.9	20.5	20.9	9.0	8.6	2.7	2.1	2.0	1.2	1.1	6.0	95.2
		Ground water recharge	6.0	8.5	32.8	8.7	5.4	0.0	0.0	0.0	0.0	0.0	0.0	16.2	77.6
		Actual evapotranspiration	0.0	0.0	13.7	28.7	61.5	110.2	96.1	51.8	50.3	44.2	9.6	0.0	465.1
		Change in ground water storage	-7.2	+0.6	+12.3	-12.2	-3.6	-8.6	-2.7	-2.1	-2.0	-1.2	-1.1	+10.2	-17.6
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-36.6	-67.6	-14.4	-5.1	+46.6	+56.7	+19.4	0.0
02HD009	1968	Precipitation	65.5	54.4	56.1	27.5	96.5	56.4	11.9	77.5	68.3	56.6	113.3	88.6	772.7
		Rain and melt	31.5	57.8	106.8								112.2	47.7	750.7
		Surface runoff	32.0	48.8	82.3	30.7	27.6	16.5	11.2	12.4	13.2	14.0	23.4	27.7	339.8
		Ground water runoff	17.8	21.1	23.1	24.4	19.6	14.0	10.7	10.4	9.4	9.2	16.3	19.8	195.8
		Ground water recharge	17.3	30.1	47.6	0.0	5.6	0.0	0.0	0.0	0.0	0.0	23.0	39.8	163.4
		Actual evapotranspiration	0.0	0.0	0.2	39.1	65.0	83.9	58.9	72.8	71.1	44.9	7.6	0.0	443.7
		Change in ground water storage	-0.5	+9.0	+24.5	-24.4	-14.0	-14.0	-10.7	-10.4	-9.4	-9.2	+6.7	+20.0	-32.4
		Change in soil moisture storage	0.0	0.0	0.0	-17.9	+17.9	-30.0	-47.5	+2.7	-6.6	+6.9	+74.5	0.0	0.0

Table 31 (cont'd)

Basin	Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
02HD009															
	1969	Precipitation	59.7	21.3	35.3	94.0	86.9	68.6	118.9	112.5	9.4	69.1	101.9	68.1	845.7
		Rain and melt	94.1	10.9	49.5	97.7							98.5	62.0	878.1
		Surface runoff	56.6	24.4	47.5	45.2	29.2	19.8	19.0	21.3	12.4	16.8	24.9	26.9	344.0
		Ground water runoff	18.3	18.5	19.3	24.1	19.3	15.2	12.7	11.4	10.2	9.0	18.5	20.1	196.6
		Ground water recharge	55.8	5.0	21.3	41.0	9.7	0.0	0.0	0.0	0.0	0.0	32.3	55.2	220.3
		Actual evapotranspiration	0.0	0.0	0.0	35.6	67.3	98.5	105.0	108.6	44.9	37.6	12.9	0.0	510.4
		Change in ground water storage	+37.5	-13.5	+2.0	+16.9	-9.6	-15.2	-12.7	-11.4	-10.2	-9.0	+13.8	+35.1	+23.7
		Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-34.5	+7.6	-6.0	-37.7	+23.7	+46.9	0.0	0.0
	1970	Precipitation	64.0	54.9	73.4	70.9	69.6	60.5	79.2	34.5	65.3	110.0	66.5	76.2	825.0
		Rain and melt	17.4	25.1	100.1	130.0								33.8	792.0
		Surface runoff	17.8	26.2	49.3	50.8	28.4	17.5	17.5	12.7	14.0	19.6	24.9	30.2	308.9
		Ground water runoff	16.0	14.2	16.5	19.0	20.3	14.5	14.0	11.7	10.2	9.2	7.8	8.3	161.7
		Ground water recharge	15.6	13.1	67.3	63.7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	161.6
		Actual evapotranspiration	0.0	0.0	0.0	34.5	70.4	101.8	100.6	48.3	67.1	47.0	13.5	0.0	483.2
		Change in ground water storage	-0.4	-1.1	+50.8	+44.7	-20.3	-14.5	-14.0	-11.7	-10.2	-9.2	-7.8	-6.4	-0.1
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-8.9	-44.3	-24.9	-14.8	-5.6	+52.6	+35.9	+10.0	0.0
	1971	Precipitation	67.1	102.6	53.1	33.3	31.2	104.4	77.7	62.0	49.3	53.8	67.8	98.6	800.9
		Rain and melt	11.5	51.7	49.7	185.6							54.0	89.8	820.7
		Surface runoff	20.8	22.6	41.9	77.7	23.4	19.0	15.7	13.5	15.2	17.8	19.0	29.7	316.3
		Ground water runoff	15.0	15.5	28.7	28.2	20.3	14.0	13.2	10.7	9.2	8.7	8.5	18.0	190.0
		Ground water recharge	5.7	44.6	36.5	115.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	218.5
		Actual evapotranspiration	0.0	0.0	0.0	21.1	66.3	103.6	101.6	71.1	55.1	54.6	2.5	0.0	476.0
		Change in ground water storage	-9.3	+29.1	+7.8	+86.8	-20.3	-14.0	-13.2	-10.7	-9.2	-8.7	-8.5	-1.3	+28.5
		Change in soil moisture storage	0.0	0.0	0.0	0.0	-38.2	-4.2	-26.4	-11.9	-11.8	-9.9	+41.0	+61.4	0.0

Table 31 (cont'd)

Basin Year	Hydrologic Process	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
02HD009														
1972	Precipitation	56.1	92.2	83.1	65.8	51.1	87.1	93.2	116.6	76.2	81.5	67.1	130.3	1000.3
	Rain and melt	32.7	23.4	74.4	189.3							66.9	98.5	991.1
	Surface runoff	32.5	24.9	37.6	102.9	28.2	19.0	19.0	22.6	17.0	23.7	28.4	37.7	393.5
	Ground water runoff	18.8	18.8	19.6	22.1	19.0	14.0	13.0	12.2	10.7	9.3	10.5	22.3	190.3
	Ground water recharge	19.0	17.3	56.4	92.8	0.0	0.0	0.0	0.0	0.0	0.0	9.7	83.1	278.3
	Actual evapotranspiration	0.0	0.0	0.0	15.7	79.5	95.8	103.0	107.7	78.0	27.4	2.3	0.0	509.7
	Change in ground water storage	+0.2	-1.5	+36.8	+70.7	-19.0	-14.0	-13.0	-12.2	-10.7	-9.3	-0.8	+60.8	+88.0
	Change in soil moisture storage	0.0	0.0	0.0	0.0	-37.6	-13.7	-15.8	-1.5	-8.1	+39.7	+37.0	0.0	0.0
1973	Precipitation	35.8	42.4	103.9	84.8	95.5	73.4	34.0	54.6	44.2	103.9	93.5	74.2	840.2
	Rain and melt	55.9	28.1	131.7									44.8	844.4
	Surface runoff	40.4	34.2	91.9	51.5	37.2	23.2	14.6	15.5	14.3	22.2	29.2	24.4	398.6
	Ground water runoff	18.1	19.7	25.3	19.2	18.0	16.1	13.0	12.4	12.1	10.3	9.7	18.2	192.1
	Ground water recharge	33.6	13.6	51.4	23.8	14.6	0.0	0.0	0.0	0.0	0.0	0.0	34.5	171.5
	Actual evapotranspiration	0.0	0.0	13.7	28.7	61.7	100.5	93.7	65.5	48.8	44.2	9.6	0.0	466.4
	Change in ground water storage	+15.5	-6.1	+26.1	+4.6	-3.4	-16.1	-13.0	-12.4	-12.1	-10.3	-9.7	+16.3	-20.6
	Change in soil moisture storage	0.0	0.0	0.0	0.0	0.0	-34.2	-61.3	-14.0	-6.8	+47.8	+64.4	+4.1	0.0

Table 34. Comparison Between Monthly and Annual Ground Water Discharge as Simulated by the Ground Water Model (S) and Estimated from Baseflow Analysis (B) for Federal Station 02HD009 (1968-1972)

(All values in mm)

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	S	15.4	17.2	18.3	20.9	20.2	16.7	14.3	13.1	12.5	12.1	13.4	15.5	189.6
1968	B	17.8	21.1	23.1	24.4	19.6	14.0	10.7	10.4	9.4	9.2	16.3	19.8	195.8
	S	16.1	16.4	17.2	18.5	16.3	16.1	14.2	12.8	11.3	9.5	14.2	16.4	179.0
1969	B	18.3	18.5	19.3	24.1	19.3	15.2	12.7	11.4	10.2	9.0	18.5	20.1	196.6
	S	16.3	15.2	15.3	16.7	17.1	15.8	13.2	12.6	11.4	10.3	9.1	8.5	161.5
1970	B	16.0	14.2	16.5	19.0	20.3	14.5	14.0	11.7	10.2	9.2	7.8	8.3	161.7
	S	13.5	13.7	18.4	18.9	18.6	16.4	15.1	12.3	10.8	9.6	9.1	12.5	168.9
1971	B	15.0	15.5	28.7	28.2	20.3	14.0	13.2	10.7	9.2	8.7	8.5	18.0	190.0
	S	15.1	15.6	16.3	18.1	18.0	15.3	14.7	13.6	11.2	-	-	-	-
1972	B	18.8	18.8	19.6	22.1	19.0	14.0	13.0	12.2	10.7	-	-	-	-

Table 35. General Characteristics of the three Major Physiographic and Climatic Environments: the Oak Ridges Interlobate Moraine, the Till Plain (the South Slope) and the Lake Iroquois Plain which are Represented by the Bowmanville, Soper and Wilmot Creeks Drainage Basin*

General Characteristics	Oak Ridges Interlobate Moraine	Till Plain (South Slope)	Lake Iroquois Plain
Extention	Niagara escarpment - Trent River	Niagara escarpment - Trent River	Niagara River - Trent River
Elevation	300-425 m	122-425 m	74-187 m
Length	160 km	160 km	300 km
Width	0-13 km	5-27 km	0-13 km
Area	1280 km^2	2406 km^2	1800 km^2
Relief	Hummocky	Rolling	Gentle
Soil	Sandy loam to sand	Loam to sandy loam	Clay loam to sandy loam
Surface geology	Sand and gravel up to 100 m in thickness and till in kame and interlobatin moraine	Predominantly till in ground moraine with some outwash sediments	Deltaic sands and clay and silts of lacustrine origin
Surface drainage	Extremely poorly developed	Well developed	Well developed
Long-term mean temperature	6.7-7.7°C	6.8-8.3°C	8.3-8.8°C
Long-term mean precipitation	750-1000 mm	700-950 mm	650-850
Long-term mean runoff	300-400 mm	325-450 mm	250-375
Long-term mean actual evapotranspiration	450-600 mm	375-500 mm	400-475
Streamflow characteristics	Small direct runoff components, significant ground water runoff component and small variations in streamflows	Equally significant direct surface and ground water runoff components and moderate variations in streamflows	Significant direct runoff component, a small ground water runoff component and significant variations in streamflows
Transmissivity	15-500 m^2/day	5-100 m^2/day	1-100 m^2/day
Ground water regime	Basically under water table conditions	Basically under water table and leaky artesian conditions	Basically under leaky and non-leaky artesian conditions
Long-term mean ground water recharge and discharge	275-375 mm	150-200 mm	50-100 mm

* This table is based on the findings in this report; Chapman and Putname (1951); Coulson (1967) and the Shawinigan Engineering Company Report (1969).